



The Tectonic Practice

In the transition from the predigital to the digital era

Schmidt, Anne Marie Due

Publication date:
2007

Document Version
Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

Citation for published version (APA):

Schmidt, A. M. D. (2007). *The Tectonic Practice: In the transition from the predigital to the digital era*. (1 ed.) Aalborg Universitet.

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

Take down policy

If you believe that this document breaches copyright please contact us at vbn@aub.aau.dk providing details, and we will remove access to the work immediately and investigate your claim.

FOREWORD AND ACKNOWLEDGEMENT

Architecture frames much of our life as built matter and tangible buildings. Likewise architectural ideals are often described and discussed in terms of the architectonic edifice that we are confronted with as the finished product. Rightly so, one might add, because the final judgement of architecture can only be in terms of the human experience of lived life in a building. Architecture is, however, much more than what meets the eye. It is also a practice that draws on technology and develops ingenious solutions in the process of creating our urban and architectural environments – it is a tectonic practice. In a time where partnering, lean construction and other management concepts call for an explicit understanding of the management of the architectural practice it seems fit to develop an understanding of how architectural ideals are created through practices that use and develop technology. This tectonic practice is what present research project revolves around. What is sought here is an understanding of what characterises such practices, what enables and obstructs it. The aspects touched upon ranges from the aim of the project to the actors and design tools involved in the creation. The introduction of the digital technology as a design tool is touched upon in this connection in order to discuss to which degree this technology is a potential to the tectonic practice. The hope is that this will enable architects, engineers, project managers and others involved with the building industry to consciously manage building projects, organise collaborative practices and create design tools that will support the creation of architectural quality and not only make building more effective and economic.

The study consists of four parts. The first part, the introduction, explains the scope of the work as such and defines the research question that is worked and describes the method by which this is sought uncovered. The second part, method, concepts and limitation, explains the methodology and unfolds the concepts used in the research question and thereby limits the study. The third part, the tectonic practice, is two essays that examine the tectonic practice in two case studies of Sydney Opera House interior design with respect to actors, design tools and approach. The fourth part concludes the study by discussing how the tectonic practice can be supported in the future for instance through the development of digital design tools.

During the course of this study a number of people has helped and encouraged the study through various means and I would like to thank them all for their support and contribution: my supervisors Adrian Carter and Poul Henning Kirkegaard for interesting discussions and supporting mentoring along the way; Jørn Utzon for his inspirational approach to architecture, Jan Utzon, Richard Johnson, Andrew Nicol, Joseph Skrzynski, Gregg McTaggart, Mat Morell and Norman Gillepie for their time and patience in shedding light on the design process of the Opera Theatre; Niels Jordan and Philip Nobis for discussions of the Minor Hall; Eoghan Lewis for his passion about the Opera House; Karl Christiansen for his passion about tectonics; Peter Blundell Jones, Michael Barron, Marshall for their time, interest and qualified critique of parts of the writings; Fergus Fricke and the rest of the Sydney acoustics lab as well as the PhD students at Architecture and Design for discussions on the scope of the research; my colleagues at Architecture and Design and my family for their support. Last but not least I would like to thank Allan Rasmussen for celebrating victories and mourning defeats with me and for his never failing interest, encouragement and presence.

TABLE OF CONTENT

INTRODUCTION

| | |
|--|----|
| INTRODUCTION | 11 |
| The mutual relationship between technology and tectonics | 13 |
| THE TECTONIC PRACTICE | 15 |
| The master builder era – inception of the tectonic tradition | 15 |
| The Industrial Revolution – the continuation of the tectonic tradition | 16 |
| The Modern Movement – initially driven by tectonics, later rejecting tradition | 18 |
| Post-modernism – re-introducing tectonic thinking | 21 |
| Challenges to the tectonic practice in the post-industrial era | 22 |
| RESEARCH FOCUS | 24 |
| The tectonic practice as collaboration | 24 |
| The digital era as an opportunity to the tectonic practice? | 25 |
| The discussion of technology versus human actors | 27 |
| Positioning the study in relation to other studies of tectonics | 28 |
| RESEARCH OBJECTIVE AND RESEARCH QUESTION | 31 |
| Objective: to support a contemporary tectonic practice | 31 |
| Research question | 32 |

METHOD AND CONCEPTS

| | |
|---|----|
| METHODOLOGY - TO CHOOSE A PATH | 37 |
| Tectonics is equally a concept, built edifices and a certain practice | 38 |
| THE CONCEPT OF TECTONICS | 39 |
| The tectonic practice | 40 |
| Selecting the cases | 43 |
| Data collection | 44 |
| INITIATION OF THE CASE STUDY - PRACTICE: BETWEEN ACTORS AND DESIGN TOOLS | 45 |
| Actor and practice – the individual conditioned by structure | 46 |
| Design tools: Artefacts as an extension of body and mind | 50 |
| CONCLUSION | 53 |
| READER'S GUIDE | 53 |
| THE CONCEPT OF TECTONICS | 57 |
| Tectonics – creating oases of order and materiality | 59 |
| Carl Bötticher – tectonics is a relation between expression and building principles | 60 |
| Gottfried Semper – tectonics is how different materials provide different expressions | 63 |
| Modernism – structure is the truth hidden beneath the architectural expression | 67 |
| Frampton - reintroducing the symbolism of structure | 68 |
| ONE TRUE TECTONIC APPROACH? | 71 |

| | |
|---|-----|
| THE RENEWING POTENTIAL OF TECTONICS | 74 |
| CONCLUSION AND LIMITATION | 76 |
| THE CONCEPT OF TECTONICS IN THE DIGITAL ERA | 79 |
| From fascination to critical assessment – the background of digital tectonics | 79 |
| Introducing the concept of digital tectonics | 80 |
| Digital Tectonics – focusing on practice instead of built edifice | 82 |
| Touching all three tectonic approaches | 84 |
| CAN THE BUILDING PRINCIPLE APPROACH BE SUPPORTED BY THE COMPUTER TOOLS? | 85 |
| Understanding the practice of tectonics in the digital era | 87 |
| CONCLUSION | 91 |
| THE TECTONIC PRACTICE | |
| THE MINOR HALL CASE | 95 |
| The Opera House – a tectonic case | 95 |
| Getting valid information about a controversial project | 98 |
| MINOR HALL DESIGN DEVELOPMENT – THE UNREALISED INTERIORS | 101 |
| Utzon seeks acoustic design advice | 103 |
| An architect's understanding of sound | 104 |
| Jordan's hesitance on design | 108 |
| New consultants and new design tools | 110 |
| Achieving a tectonic Building Principle | 112 |
| Sophisticated standardisation | 115 |
| WHAT MADE UTZON ABLE TO CREATE TECTONICS IN THE MINOR HALL? | 117 |
| Building Principle tectonics – enabled by actors with the right tools | 118 |
| Jordan and the inspiration from classic auditoria | 119 |
| Cremer, Gabler and the creation of ready-to-hand design tool | 120 |
| Utzon and the tectonic intention | 123 |
| CONCLUSION - ACTORS SUPPORTING THE EARLY DESIGN STAGES ENABLE THE TECTONIC PRACTICE | 124 |
| THE OPERA THEATRE CASE | 127 |
| From dismissal to re-engagement of Utzon | 127 |
| Conservation or refurbishment | 129 |
| The Opera Theatre – two out of six refurbishment projects | 130 |
| THE OPERA THEATRE - UNDERSTANDING THE EXTENT OF THE PROJECT | 132 |
| Third time lucky? Stepped clouds billowing again | 134 |
| Redefining the fan | 138 |
| The cunning curves of the ceiling | 139 |
| Towards a shoebox shape again | 141 |
| Computer simulations solving the details of the design | 142 |
| An Utzonian Opera Theatre | 143 |
| Heritage listing open to future changes | 147 |
| BUILDING PRINCIPLE TECTONICS - ENABLED BY ACTORS WITH THE RIGHT DESIGN TOOLS | 147 |
| Richard Johnson, Jan Utzon and the realisation of Jørn Utzon's intentions | 148 |
| Arup Acoustics – a design oriented practice | 150 |

| | |
|--|---------|
| Design tools supporting each profession | 152 |
| CONCLUSION - ARCHITECTS AND ACOUSTICIANS AS CO-DESIGNERS | 153 |
| CASE COMPARISON | 157 |
| The similar tectonic edifices of the Minor Hall and the Opera Theatre | 157 |
| The dissimilar tectonic practices of the Minor Hall and the Opera Theatre | 158 |
| THE TECTONIC PRACTICE – DESIGN TOOLS AND ACTORS | 159 |
| Crucial stages to support | 166 |
| Actors and the ability to enable a tectonic practice | 167 |
| Design tools and the ability to enable a tectonic practice | 169 |
| The digital turn of design tools | 172 |
| CONCLUSION - ACTORS AND DESIGN TOOLS ENABLING THE TECTONIC PRACTICES | 174 |
| CONCLUSION AND PERSPECTIVES | |
| CONCLUSION AND PERSPECTIVES | 179 |
| SUMMARY | 179 |
| OVERALL CONCLUSION | 184 |
| THE IMPACT OF DIGITAL DESIGN TOOLS ON THE TECTONIC PRACTICES | 186 |
| Tectonic practices with traditional technologies supported by the development in digital tools | 186 |
| Tectonic practices with new technologies on the way to become supported by digital tools | 187 |
| SUMMARY OF FINDINGS | 190 |
| VALIDITY | 191 |
| Internal validity | 191 |
| External validity | 193 |
| IMPLICATIONS | 194 |
| Contribution to the research field | 194 |
| Implications | 195 |
| APPENDIX | |
| APPENDIX | 199 |
| ARTICLE | 201 |
| INTERVIEWS | 215 |
| BIBLIOGRAPHY AND ILLUSTRATION CREDITS | |
| BIBLIOGRAPHY | 283 |
| ILLUSTRATION CREDITS | 293 |

INTRODUCTION



INTRODUCTION

A great building must begin with the unmeasurable, must go through measurable means when it is being designed and in the end must be unmeasurable.

Louis Kahn
(Lobell, 1979, p. 48).

The practice of architecture has changed radically over the last 200 years with the consequence of endangering the time-honoured quality of architecture, tectonics (Frampton, 1995). Architectural tectonics is often considered to be the inevitable in building – the pragmatic concerns of materials, joints and construction that an architectural idea needs to adhere to in order to be build. This is how the concept is often used in everyday language. In a broader understanding, however, tectonics has been one of the major sources of inspiration throughout architectural history; one example of this is the Modern Movement's expression that was driven by the development of new materials, new technologies and new knowledge as well as the new architectural expressions pushed the development of these aspects (Beim, 2004).

In this understanding, which this research subscribes to, architectural tectonics is not just a matter of developing an architectural idea from the abstract into a buildable construction but a matter of developing an architectural idea with respect and appreciation of the pragmatic and poetic aspects of its materiality. In this understanding architectural tectonics becomes an exclusive term that does not apply to all works of architecture.

Architectural tectonics can in the exclusive understanding still be understood in three different levels; as a quality stamp that can apply to architectural edifices, as a certain way of thinking about architecture found in the writings within the tectonic movement and (as it will be argued here) as a certain way of working with architecture through a tectonic practice. This kind of architectural practice deliberately attempts to develop the architectural expression by playfully working with the technical aspects as inherent to the architectural form.

The tectonic practice can be understood as a full scale architectural laboratory; a laboratory where scientific knowledge, production techniques and new materials are tested in practice. Thereby the tectonic practice does not only ensure a continuation of a long building tradition, it also holds the potential to develop the built environment. This development can for instance happen through the use of new technology. Likewise the tectonic practice can develop other areas in the building industry when an architectural expression calls for a new application of materials, production techniques or knowledge. As Tombesi (2005) has argued, the real economic value of architecture should be understood as a potential to develop the methods and products of the building industry rather than only the physical building left after the process. The tectonic practice is therefore valuable to support and uphold from many points of views – to maintain an architectural tradition of material and tactile quality, as an architectural strategy to absorb new technology into the built environment and from an economic point of view to develop knowledge and technology in the building industry.

The changing conditions of the architectural practice can fundamentally be described as the move away



Figure 1: Materiality and tactility

from the master builder to a modern building industry with professional specialisation, industrial production methods and increasingly complex demands to building projects. This move has challenged the tectonic quality of architecture. The reactions to the changing building industry have been met by resignation from the majority of architects, while few celebrated the changing conditions (Venturi, 1998) and others called for a resistance towards the devaluation of the tectonic quality of architecture as they argued would be the consequence. This call for resistance came especially from Kenneth Frampton (1990, 1995) who reintroduced tectonics as an architectural movement.

Frampton's work was highly influential but also highly controversial because it was understood as utopian – how was the ordinary architect to live up to the tectonic ideals in the contemporary context? This objection was, from the author's point of view, valid especially because Frampton restricted his interest in tectonics to the tectonic edifice. While he pointed out what challenged the tectonic tradition (politics, economy etc.), he did not describe any strategies as to how to practice tectonics in a contemporary context far from the master builder role of the architect. Even though this shortcoming of Frampton's writings on tectonics has to some extent been addressed by Marco Frascari (1984) with his distinction between construction and construing and Anne Beim's identification of tectonics as an architectural inspiration (2004), tectonics remained to be seen by many (for instance Davey, 1997 and Davies, 1996) as a desirable quality of architecture that unfortunately was intimately connected to the long gone master builder era or limited to the few privileged architects who had the economic freedom in their projects to be able to still work like master builders.

The gap between architectural tectonics as a quality of the architectural edifice and the context of the architectural practice persisted for almost a decade. In this vacuum in the understanding of tectonics, Neil Leach found his niche. He and a number of other authors introduced the computer as the newly found possibility to revive the tectonic tradition and called the new alliance digital tectonics. Through the ability of the computer, the architectural expression had become increasingly complex; the evaluation of architectural schemes had become swift as well as the architect could communicate with the industrial production through the digital technologies. These abilities of the computer, they argued, offered themselves to a revival of the tectonic practice (Leach et al, 2004).

There is little doubt that the introduction of the computer has signified great changes to the creation of architecture generally (Zellner, 1999; Kolarevic, 2003). What remains a question is to what degree the introduction of the computer is a potential to the tectonic practice specifically. This discussion has only been initiated. Here it is argued that such a discussion is hindered by the lack of understanding of the mechanisms behind the tectonic practice; of what enables and obstructs this kind of practice. Without this understanding it is difficult to conduct a qualified discussion of whether the introduction of the computer is a potential to the tectonic practice.

The mutual relationship between technology and tectonics

The authors of the digital tectonics (Beesley and Seeböhm, 2000; Ham, 2003; Jabi, 2004; Leach et al, 2004; Gao, 2004; Liu and Lim, 2005a, 2005b) argued that there is a relationship between the new digital



Figure 2-5: The Classic architecture displayed the post and lintel principle. The Gothic architecture used a new structural principle to achieve lightness. The large spans of new building types in the Industrialisation called for new principles.

technology and tectonics as a practice. A relation that they argue should be understood as a potential to the tectonic tradition. The thought of a mutual relationship between technology and tectonics is not new. In fact one of the factors that most authors on tectonics (Semper, 1841; Frampton, 1995; Beim, 2004) stress as significantly influencing architecture and the tectonic realm is technology.

In connection to tectonics as a built edifice this is evident in many instances in the architectural history. When examining the buildings of primitive cultures this relationship is apparent because the ability to use an axe or the development of ceramics for instance influenced the way of building and new artistic expressions developed. Also the reversed situation can be found: new artistic directions gave rise to the development of related skills. Technology and tectonics is as such closely related and new technological conditions can inspire architects to take advantage of the new possibilities in their architecture. Examples of this are Mies van der Rohe's use of the new steel I-beam that enabled higher and more elegant high-rises such as it can be seen in the Seagram building in New York. Likewise Walter Gropius' use of the glass curtain wall in the Bauhaus school enabled an almost transparent building with a close connection between the outside and the inside. Also Le Corbusier's free plan was like Gropius' building dependent on the new technology that from a structural point of view rendered the outer wall redundant. The high-rise, the transparent building and the free plan are thus all architectural motives that are fostered by a conscious use of new technology.

When the authors on digital tectonics introduce the computer technology as an aspect influencing the tectonic tradition, it is however, not tectonics as a built edifice but tectonics as a practice that they are focusing on. Unlike an axe where the movement of the blade creates certain patterns and thereby holds a specific artistic potential, the potential of the computer in architecture is more complex because it also influences the practice of architecture. To what degree the claim of the computer as a potential to the tectonic tradition holds true and in which manner the tectonic tradition can actually be supported by the computer technology is, however, still to be understood.

The writings on digital tectonics as well as the emergence of this new technology therefore highlight the need to understand the tectonic practice. Through an understanding of tectonics as a practice it becomes possible to discuss the ability of the computer technology in connection to tectonics. To begin to under-



Figure 6-8: Modern architecture was inspired by and developed new building technology. Post-modern architecture on the other hand was more concerned with historical references and the re-introduction of tectonics was partly a counter-reaction.

stand how the new computer technology can affect the practice of tectonics, an understanding of the aspects that presents themselves as challenges to the creation of tectonics in a contemporary context is an excellent starting point.

THE TECTONIC PRACTICE

The master builder era – inception of the tectonic tradition

The inception of the tectonic tradition is merged with the beginning of the era of the master builder. This era began when people around 8000 BC began to settle in cities instead of living as nomads (Mitchell, 1999). Before that time every individual was his or hers own architect and constructed the shelter for the night. The new urban condition gave rise to a new division of labour. With a more settled society, it made sense to refine the building technique because the constructions were now expected to be more durable and the building technique became more complex. An artisan class who was the building experts developed. Tectonics is inherent to the name of the profession architect, which is a contraction of the Greek word *archi* that means master and the Greek word *tect* that means builder and is related to the word tectonic (Frampton, 1995).

In this era the architect worked with architecture and materials hands-on on the building site; a position in which he was in charge of every aspect of the architectural process. Through a trial and error method passed on from the master architect to his apprentices, the architect learned about the strengths and weaknesses of a material through the success or failure of the construction. Knowledge about construction, proportions of space, colours, the movement of the sun, the resonance of the human voice against stone and the flow of air through chimneys was gradually improved and passed on from master to apprentice through generations of architects. The development of the field was incremental and the knowledge base was often one part myth and one part empirical observation. Vitruvius' ten books on architecture (Vitruvius, 1960) from the first century, for instance, ascertained that architecture should strive for the same harmony as the Gods had structured the whole universe from. A call for a more rational approach to architecture, while still maintaining a close relationship between religion and architecture, was heard from another of the great architectural writers, Leon Battista Alberti, during the 15th century (Alberti, 1988).

Despite the rather unreliable knowledge base, the master builder approach to architecture enabled the development of a building culture in which the knowledge of materials and techniques of execution was refined – a tradition of tectonics emerged.

Gottfried Semper; who is often considered to be the father of the tectonic movement; and his writings on tectonics can be seen as born from the master builder tradition because he likens the architect's work to that of an artist who has his hands on the materials. This is evident in his discussion of style in architecture as developed through the character of materials and the techniques available to refine the materials (Rykwert, 1972). Semper understands tectonics as closely related to the handicraft connected to each material and sees the architect as directly connected with the materials of the architectural edifice.

The Industrial Revolution – the continuation of the tectonic tradition

With the Industrial Revolution, beginning in the middle of the eighteenth century in England and subsequently repeated in other countries, the era of the master builder was largely outplayed. The introduction of machines to replace the physical strength of human beings and animals fuelled an industrial production where the low cost of each item quickly outplayed the artisan production of artefacts. This also had its impact on the practice of architecture. Where the craft based production on the building site had been the norm during the master builder era, the production of building elements in factories became the norm in the industrial era. The era can be said to be epitomized by the Crystal Palace by Joseph Paxton from 1851.

In many respects the industrialisation was a positive development because the standardised production resulted in building elements of a high quality to a low price. But the industrialisation also challenged the tectonic tradition because the architectural practice and the role of the architect changed. When the processing of materials and structural solutions were no longer developed and refined at the building site, the design was separated from the material aspect of architecture because the design had to be carried out in order for the industry to manufacture the building components. The necessary number of building drawings therefore increased, and consequently the architect moved out of the building site and into architectural offices. "With great division of labor, architects distinguished themselves from craftsmen and moved off-site, and materials and components could be acquired through trade rather than created locally." (Mitchell, 1999, p. 213). These changes were spatial, where the practice of architecture had primarily been centred around the building site it was now split between the building site, the architect's office and the industrial factories.

The changes to the architectural practice were not only caused directly by the industrialisation but also indirectly by changing demands to architecture. During the nineteenth century, the massive population growth resulted in a large-scale urbanisation. Large housing districts grew up and the property speculator – unlike the architects' former clients – valued price and speed over architectural quality (Benevolo, 1996). These temporal aspects also presented a challenge to the tectonic tradition.

"No longer considered as long-lasting cultural and social repositories, buildings came to be viewed as economic investments with an intentionally planned short existence." (Frascati, 1984, p. 26).

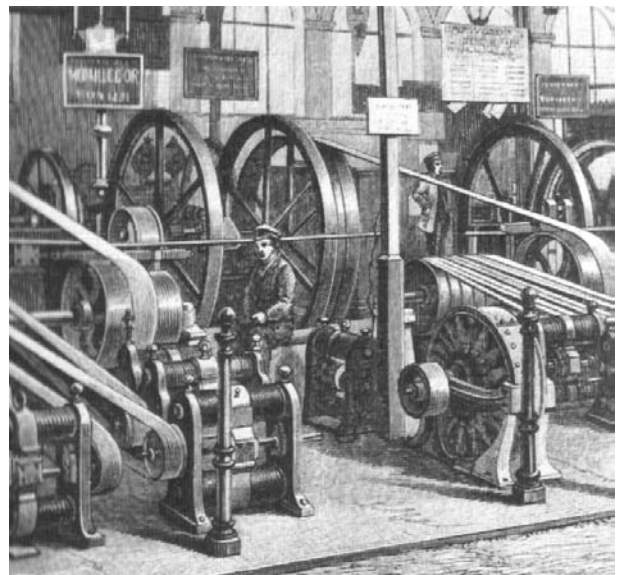
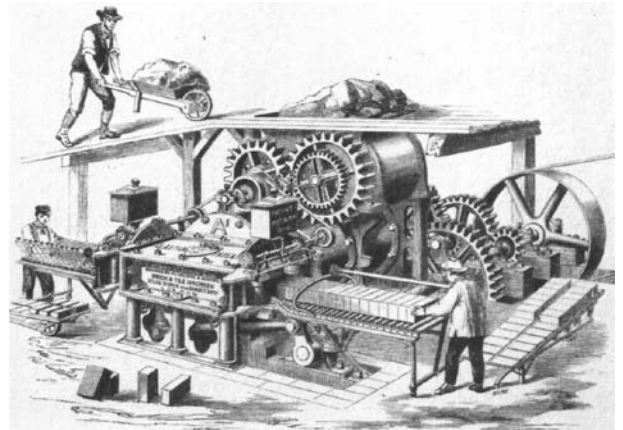


Figure 9: Crystal Palace
 Figure 10: By the middle of the century machines had been designed to do all kinds of standardised and repetitive jobs, among them moulding bricks
 Figure 11: Generation of electricity with an elaborate system of belt-driven dynamos. Around 1873.

The spatial and temporal changes were paralleled by a change in thinking that happened during the eighteenth century. Architecture had long been content with being based on part empirical observations and myths, but the Enlightenment wanted to rid all professions of superstition, tradition and influence from religion. While the Enlightenment project was sympathetic and quite desirable in connection to professions such as medicine and astronomy, it had grim consequences when applied full-heartedly to architecture. The thinkers in the Enlightenment dismissed all knowledge that was not based on empirical data and experiments thereby challenging the poetic and artistic aspects of architecture. Francis Bacon, for instance, argued that "Houses are build to live in, and not to look on; therefore, let use be preferred to uniformity, except where both may be had." (Bacon, 1961).

The part of architecture that was reliable knowledge, according to the rationale of the Enlightenment, was collected in the engineering profession. These fields quickly gained scientific merit and developed into fields separate from architecture (Hale, 2000). Where the empirical knowledge in the master builder era had been developed at the building site in a project specific context, the engineers had like the architect now moved out of the building sites and were taught to understand pure, objective, scientific knowledge as their aim. In 1795 the Ecole Polytechnique was founded in Paris (Benevolo, 1996) and here engineering was taught as applied science. This reinforced the growing specialisation of architecture and engineering. The manner of viewing engineering as applied science – the application of theoretically founded knowledge – contrasted the tectonic understanding of technique in building where the knowledge about materials and their abilities were developed in an evolutionary manner on the building site. This shift in thinking is thus the beginning of the development of differing rationales within the building industry as well as the gap between the professions of engineering and architecture created the organisational challenges that are still prevailing today.

As an opposition towards this reduction of architecture and in defence of the tectonic tradition, Carl Bötticher wrote about tectonics in the 1850ties. His writing, as opposed to Semper's, addressed the future of the tectonic tradition and his thoughts on the relationship between core-form (the structural core of the building) and art-form (the explanation of the structural form through ornaments) can be seen as addressing the dichotomy between engineers and architects that had emerged in the practice of architecture (Bötticher, 1846). In this new industrial context it was necessary for the professions to work together in order to create tectonics.

The Modern Movement – initially driven by tectonics, later rejecting tradition
Bötticher was thus the architectural writer who pointed out the way for the tectonic tradition into the new industrialised era by for instance addressing metal as the new material that should serve as the basis of a new architectural expression. The Modern Movement in architecture can be seen as a result of this search for an architectural expression appropriate to metal and other new materials such as concrete and large panes of glass. The rationale of the Modernist Movement was initially driven by a tectonic consideration (Oechslin, 1993) and to the earliest modernists; the understanding of tectonics was a pre-condition that enabled them to develop their architectural expression - not a tradition that restricted them.

Despite the foundation of modernism in the tectonic tradition, the architects of the later Modern Movement soon came to understand themselves as avant-garde architects who had broken with history (Kruft, 1994). This self-understanding was the first step in a rationalistic understanding of architecture that characterised the late modernism where the subjective, symbolic and decorative aspects were rejected as subjective and superfluous. Reyner Banham criticised this development where the aesthetic and symbolic aspects were forgotten in the later Modernism and argued that it was partly due to the architects' defence of Modern architecture,

"With the International Style outlawed politically in Germany and Russia, and crippled economically in France, the style and its friends were fighting for a toehold in politically-suspicious Fascist Italy, aesthetically-indifferent England, and depression-stunned America. Under these circumstances it was better to advocate or defend the new architecture on logical and economic grounds than on grounds of aesthetics or symbolisms that might stir nothing but hostility. This may have been good tactics – the point remains arguable – but it was certainly misrepresentation. Emotion had played a much larger part than logic in the creation of the style..." (Banham, 1960, p. 321)

The rhetoric was powerful and soon Henry Ford's invention of the linear assembly line became the favoured model for understanding architectural production (Abel, 2004) where standardisation was the key to an economic and rapid production process. While the tectonic tradition as well as the early Modernists had understood the new technology and building industry as an opportunity to the architectural profession, the late Modernism seemed to understand architecture as determined by the building industry. This understanding can be



Figure 12: Mies van der Rohe, Seagram Building

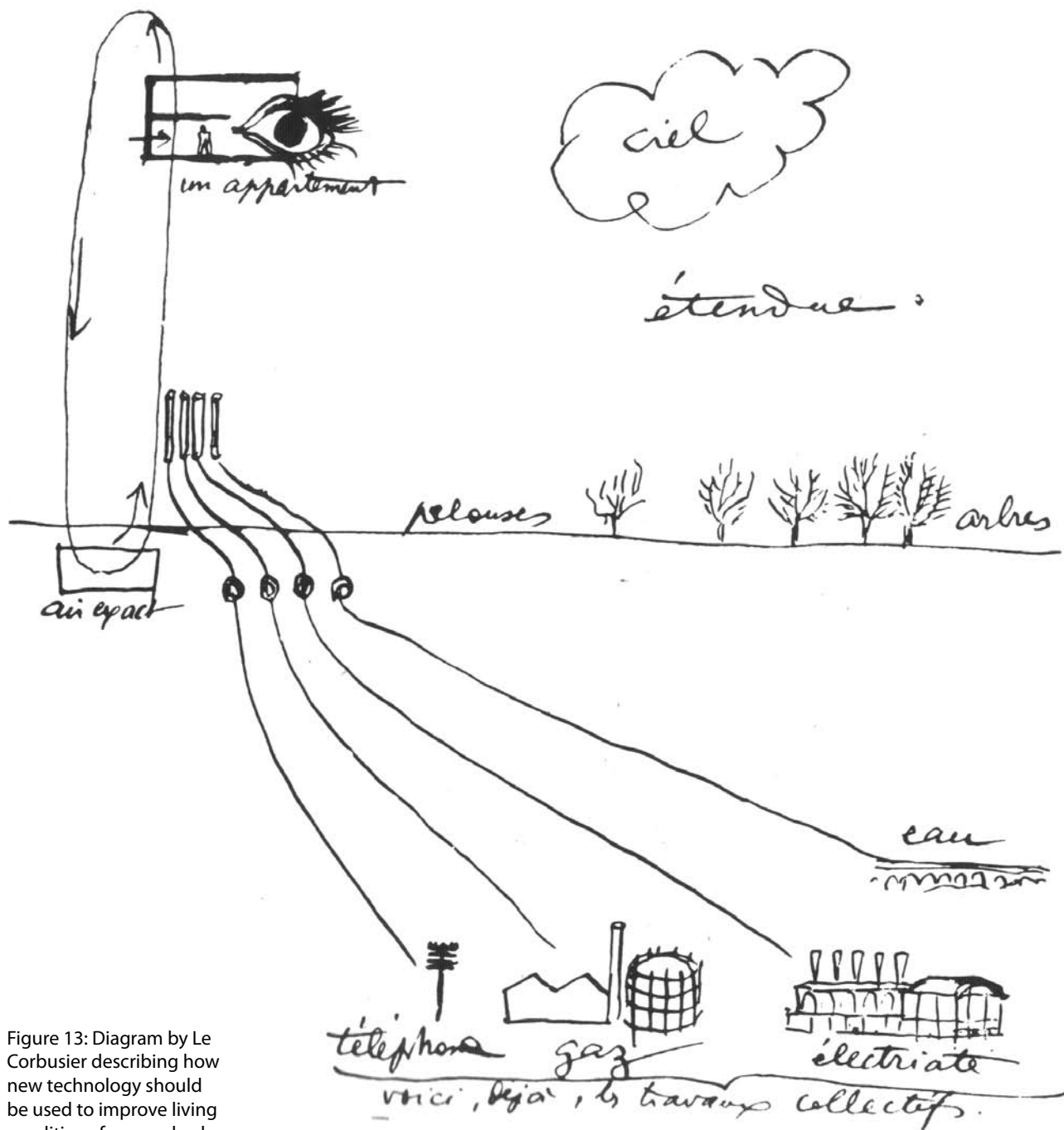


Figure 13: Diagram by Le Corbusier describing how new technology should be used to improve living conditions for everybody

seen demonstrated in its extreme when endless concrete housing blocks were erected with the distance between them determined by the most rational track for the erection crane.

During the later part of Modernism the architectural profession was pushed away from its former key areas with the increasing size and strength of the engineering and contractor professions (Mainstone, 2001). Likewise from the side of the client, the field of architecture was pressured even more to deliver 'value for money', where value was measured primarily in number of square meters rather than quality of the building.

The architectural practice of this period demonstrated firstly how difficult it was to create tectonic architecture in the new technological paradigm and under the influence of an overly rational and economically centered environment and secondly a general amnesia of the tectonic traditions and the writings of Bötticher and Semper - the ability to create tectonics was largely forgotten.

Post-industrialisation – re-introducing tectonic thinking

This amnesia continued into post-modernism. The poverty of the environments created in the late modernism resulted in a questioning of modernism in general and a renewed interest in history occurred (Colquhoun, 1984). The architectural practice of this period was still characterised by being sidetracked by other professions in the building industry, and architecture was often reduced to a mere superficial endeavour. While Venturi (1989) and other post-modern architects decided to accept the conditions of the time by perfecting the art of façade design, a new interest in tectonics was also provoked by the marginalisation of the architectural profession. Gevork Hartoonian describes how the Modernity was in the post-modernism followed by an opposition led by Kenneth Frampton (Hartoonian, 1997).

This movement was supported by a growing impatience with the standardised products of the industrialisation. Again the car industry is an illustrative example of this development. Where the industrialisation had depended on the industrial and standardised production of limited product types, the market for these products diminished during the 60s and 70s. Instead the consumers wanted different types of products (Shodek et al, 2004). This also applied to architecture. The buildings that twenty years before had been popular because they were sanitary, well constructed and modern, were now by many seen as rigid, repetitious and un-humane (Nesbitt, 1996).

It was in this climate that the tectonic movement was revived. A number of writers (Sekler, 1965; Gregotti, 1983; Frascari, 1984; Frampton, 1980, 1982, 1990, 1995 and Beim, 1999, 2004) asked themselves whether there were not some very significant lessons to be learned by the early modernists and the few other architects that had been able to keep the tectonic tradition alive. Kenneth Frampton's writings, for instance, argued for a continuing – however sporadic – existence of a tectonic architecture and exemplified this point through the works of six architects that are seen to continue the tectonic trajectory. Frampton's writings on tectonics (1995) are at the same time a criticism of the late Modernism that had become dominated by the rationales of efficiency, rationality and economy and of Post-modernism that applied superficial historical references. Likewise Anne Beim (2004) investigates the consequences to the tectonic edifice

when the production of materials and components becomes industrialised.

The writers of this period concluded that the tectonic tradition is not dependent on the master builder tradition by pointing to a number of architects who were able to practice tectonics in a different era. These architects were thus able to overcome the spatial, organisational and temporal challenges to the tectonic practice. With this said, the writers of this period do argue that the tectonic practice is under pressure and they (especially Frampton, 1995) argue that the architectural profession is partly to blame due to its acceptance of the superficiality of the architectural practice. For the tectonic practice to survive both Beim and Frampton point to the architects' responsibility to go beyond a superficial and purely aesthetic concern with architecture and instead become involved in the materiality of architecture by a deliberate use of technology.

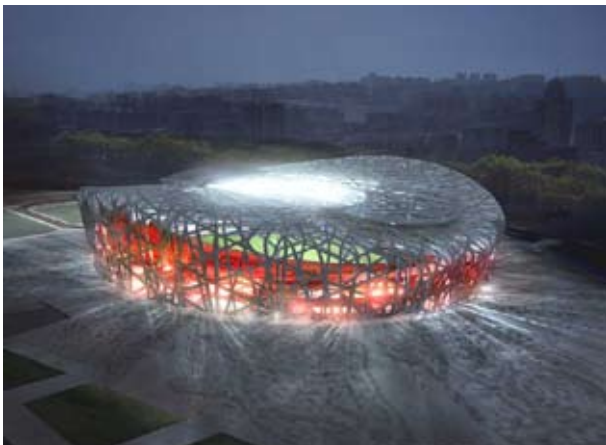


Figure 14. Herzog & De Meuron Beijing Stadium

The tectonic tradition did not die with the master-builder and can as such not be said to be restricted to the master builder role of the architect. However, the tectonic practice changed significantly spatially, organisationally and temporally due to the new technological paradigm.

Challenges to the tectonic practice in the post-industrial era

The transition from the master builder era to an industrial building industry has had positive bearing on many aspects; building has become less expensive and thereby within reach of the most people, the quality of building elements has become standardised with an even quality as the result, the knowledge that the building industry is based upon is empirically tested and developed. Due to the same changes, however, the tectonic practice has been met by a number of challenges. Without

claiming that the list is exhaustive, a list of challenges is presented:

Challenges caused by a spatial change in the practice of tectonics

- The practice of tectonics has moved from the building site into the office with the consequence of an increased emphasis on documentation drawing and administration
- The production of building elements has moved from the building site into factories with the consequence that the architect has no contact with the production technology used to fabricate the building elements
- The engineering and architectural professions are often physically placed in different offices thereby increasing communication barriers

Challenges caused by changes to the organisation of the tectonic practice

- The tendering system creates an organisational barrier with the consequence that the architect cannot be certain that the material intended to be used during the design process and the material actually used in the construction process are the same
- The organisation of the building industry with building contractors being liable for construction faults and the architect freeing themselves of liabilities marginalises the architect and thereby the ability of the architect to influence decisions on structure, construction, materials and other tectonic aspects (this aspect varies from country to country but is applicable to Denmark and Australia)
- An increased number of specialisations introduced to handle the increasingly complex requirements in terms of energy consumption, fire regulations, building codes etc. has each their professional standards that are not necessarily sympathetic to a tectonic ideal of the architect
- The clients have changed from being wealthy patrons to being commercially interested, developer companies with the consequence that the architectural quality is not a goal in itself but a commercial aspect only desirable if it heightens the economic value of the property

Challenges caused by changing temporal conditions in the tectonic practice

- An increased number of collaborators have introduced an increased length of the line of communication and information with the consequence that the collaboration necessary to create tectonics is made more difficult
- An increased time pressure reduces the design period thereby challenging the development of new prototypical architectural solutions
- The management of architectural projects often understands a design project as a linear process thereby rendering a holistic, tectonic approach difficult

Many of the challenges are naturally connected, for instance the increased number of collaborators is connected to the increased emphasis on documentation drawing and administration. While an obvious conclusion to such a list of challenges could be that the tectonic practice is restricted to the master builder era, the findings of Frampton (1995), Frascari (1984) and Beim (2004) argue that it was possible for some architects to create tectonics even after the master builder era.

The situation is therefore not an either-or between the tectonic practice and the industrialised building industry. Rather it is possible for some architects to maintain the tectonic practice in the context of an industrialised building industry – in their practice the situation is thus both-and.

When understanding the tectonic practice as something that should be maintained and supported, it is extremely interesting to learn more about these kinds of practices and to understand how they meet and negotiate the challenges presented to the tectonic practice.

RESEARCH FOCUS

The tectonic practice as collaboration

Within the limits of this research project, it is necessary to focus on only a small section of the challenges and the investigation will therefore focus on the organisational and actor-based challenges to the practice of tectonics. The specific challenge in question is the split between the architect and the engineering consultant.

This focus is chosen for several reasons. Firstly, this challenge is a growing one in the building industry. An increasing amount of specialisations is introduced to the building industry, each with their own interests and professional background, thereby adding to the challenge. Secondly, at least in the education of Danish architects, the architectural education has increasingly focused on architecture as spatiality, not as materiality, thereby to some degree abandoning the ability to work with new technology and fields of knowledge as inherent to the architectural expression. This is particularly pronounced in connection to fields of knowledge adjacent to the architectural profession (that the consultants have taken charge of) while the application of new materials and new building systems is less problematic. Thirdly, the background of the author as part architect and part engineer from Aalborg University's newly incepted cross-disciplinary education has played a role in the choice of research focus. The argument from Ottar Brox (1998) that a personal interest from the researcher is not a problem in the selection of the research focus (while it is in the data collection and analysis) has here served as the guiding light. That the tectonic practice as collaboration lies within the professional interest of the author and the institutional background of the research does, as Brox argue, not present a validity problem but rather a natural starting point of a research project.

As with the other challenges to the tectonic practice, the split in professional specialisation between architects and engineers is a double-edged sword. The specialisation has a rational benefit because each actor can become an expert in each their field instead of trusting one person to be proficient in all fields. In many respects the professional split has been positive to all fields because they enabled each field to grow. It has, however, also enabled each field to develop without a common rationale and way of thinking about building. The scientific knowledge developed by the engineering communities, for instance, is on one hand important information to develop the building culture from, but is on the other hand difficult to absorb and transform into design information for the architects (Mainstone, 2001; Zhang, 2005).

The research focus is therefore the tectonic practice as collaboration and the aim is to investigate to what degree the new computer technology is an opportunity to the tectonic tradition.

The digital era as an opportunity to the tectonic practice?

The focus on the computer in this research project is not on the computer in itself but on how the computer programmes as design tools obstruct or enable the tectonic practice. Twenty-five years after the introduction of AutoCad, the digital technology has become much more than a mimic of the pencil drawing and physical model of the architect. As Mitchell (1999) has remarked upon, the media has evolved from being so simple that it inhibited the architect in his visual language, to being so advanced that the digital is the only place where it is possible to create the complex shapes of contemporary architecture. Many layers of this digital development are still present and evident in the palette of tools that is used by the architects and engineers today.

Beginning from the simplest, there are the two-dimensional drawing-aids and image-production (such as AutoCad, Photoshop and Illustrator) that could be characterised – as Kvan et al (2004) does - as the digital versions of the drawing boards and collage-production.

A step up the ladder in complexity we find the three-dimensional modelling programs, which are primarily used for spatial investigations and used in the production of digital snap-shots of the architectural object as a supplement to or instead of the perspective drawing (e.g. ArchiCad, FormZ, 3d Studio Viz). The complexity of these programs has evolved over the years and took a major leap with the general introduction of the Bezier-curve in the 1980'ties (Lenz, 2000). Some of these programmes are based on information from the component producers by drawing on libraries of building components (for instance ArchiCad) while other are based on the manipulation of primitives (for instance FormZ).

Another step up the ladder we find a separate branch of the three-dimensional programmes - the parametric modelling programs recently introduced. These programs shift the attention from the production of images to the production of geometrical relations in the architectural form and introduce mathematical formulas as generative factors to the architectural shapes. Some of the programs communicate well with the component production by producing the input to the production machines directly. This is for instance the case with Catia. This link is, as Mitchell (1999) remarks, also increasingly necessary because the geometries described in the three-dimensional universe are not reproducible in the standard plan and elevation format.

The last group of programmes is the analytical tools which primarily enter the architectural realm through specialist consultants. Potentially the architectural consequences of the analyses in these tools can have a great impact on the architectural form and must therefore likewise be considered as a design tool connected to architecture. To describe the phenomenon, Branco Kolarevic (2004) coined the term Performative Architecture to describe contemporary architecture that often needs to perform extraordinarily in a special area. Therefore analysis of the area; for instance acoustics, climate or construction; is required and responded to in the architectural form.

When the digital technology is proposed as an opportunity to the tectonic practice, it is not the simple ability to produce digital drawings in AutoCad that is focused upon. Rather it is the ability of the more complex three-dimensional modelling, generation and analysis programmes that is in focus.

With the research focus being on the professional split between architects and engineers, the focus on the computer programmes become whether they enable the professionals to collaborate across the professional boundaries. In this respect it is only some of the computer programmes that are interesting. In "Blurring the Lines" (Chaszar, 2006, p. 8) André Chaszar lists five central abilities of computer programmes. Combined with the understanding of the growing complexity of the computer programmes, these five abilities can be used to describe the focus and limitation of the current study,

- visualisation – the ability to present graphical information realistically, or otherwise attractively or instructively, to produce physical models aiding comprehension of 3D forms and to animate 4D sequences;
- computation – the ability to perform numerical or even text operations at high speed and with great accuracy, whether for specific solutions or a range of scenarios;
- geometric manipulation – the ability to deal with forms of great complexity (perhaps hitherto intractable) or relative simplicity, arranging, generating, measuring, modifying and realising them with, again as in computation, improved speed and accuracy;
- standardisation – the ability to faithfully communicate data from one instance to the next, allowing repetition of a particular design solution in recurring design situations;
- rationalisation – the ability to make explicit (and so editable) the decisions leading to particular design solutions, similar to standardisation but actually allowing for great variability.

In the tectonic practice as collaboration between actors, it is primarily the computation ability of the computer that is in focus. This ability is most often manifested as the calculation and simulation programmes of the engineering consultant. The visualisation and geometrical manipulation will be taken into account as well because these programmes will often be used by the architect and thereby present the computer tools on the architectural side of the collaboration.

The standardisation and rationalisation are highly connected to the production of the architectural scheme and could be interesting to investigate in connection to the collaboration between the building element suppliers and the architect but falls out of the immediate research focus in this study.

The writings on digital tectonics argue that the computer holds a potential in connection to the creation of tectonic architecture because the digital technology brings with it an ability to structurally refine complex architectural shapes, clarify the advanced geometries into components and ability to communicate the geometries to the building industry digitally instead of blueprints. Thereby the ability to work directly with materials, components and structures that was limited by the industrialisation, could be regained through the digital technology (Beesley and Seeböhm, 2000; Ham, 2003; Jabí, 2004; Leach et al, 2004; Gao, 2004; Liu and Lim, 2005a, 2005b). Thereby the writers claim that the digital era is an opportunity also to the tectonic practice.

Whether the computer actually does hold a potential in addressing the challenge of the professional split between the engineer and the architect is still to be learned. The method of investigation will be to compare a tectonic practice in a pre-digital era with one in the digital era and thereby learn to what degree the introduction of the computer actually makes a difference.

The discussion of technology versus human actors

As mentioned, tectonics and technology can be understood as being positioned in a mutual relationship. The writings on tectonics can roughly be understood in three groups – the historical, the traditional and the digital where each of the three groups has each their take on whether it is primarily the technology available or the actors involved that enables a tectonic practice.

The historical group consists of Gottfried Semper (1851, 1860, 1869) and Carl Bötticher (1844, 1846), both from the nineteenth century and both front figures in developing tectonics into an architectural movement. The second group, the traditional group, consists of Kenneth Frampton (1982, 1983, 1995), Eduard Sekler (1965), Marco Frascari (1984, 1991), Vittorio Gregotti (1983) and Anne Beim (1999, 2004) (here the emphasis will be on Frampton and Beim) who were all writing in the mid to the late twentieth century and re-introduced tectonics as an architectural movement. The last group of writings belongs to the digital era and all deal with tectonics as digital tectonics. To this group belong the writings of Philip Beesley and Thomas Seeböhm (2000), Jeremy Ham (2003), Wassim Jabi (2004), Neil Leach et al (2004), Wan-Ping Gao (2004), Yu-Tung Liu and Chor-Kheng Lim (2005a, 2005b) (here the emphasis will be on Leach).

The historical group naturally does not include speculations on computer technology in its writings but understands tectonics as conditioned (but not determined) by the technology at hand. Bötticher understands the technology as more influential on the architectural expression than Semper who maintains the human being and his free artistic will as the starting point of any architectural creation. Both, however, understand materials, technique and structural principles as immediately influencing the architectural expression and thereby the artistic freedom of the individual architect.

The traditional group likewise does not include the computer to their thinking on tectonics. This is true even if many of the writings (for instance Frampton and Beim) are written in a time where the computer was increasingly used in architectural practices. Hence the choice of the prefix traditional to this group. Much alike the historical group these writing understands technology as a condition that influences but does not determine the tectonic expression. Beim focuses explicitly on technology and argues that it is often used as a source of inspiration (Beim, 2004). Frampton's focus on technology is more implicit in his description of the tectonic edifices of six architects (Frampton, 1995). Both however focus on technology in connection to the architectural edifice and understand the use of technology during the design as an inspiration that can be used by each individual architect.

The last group, the digital tectonics, argues that the computer has moved past being used only for aesthetic display and therefore endows the computer with an ability to create a new digital tectonics,

“...computer technologies have infiltrated almost every aspect of architectural production, and are now being used to offer insights even into the realm of the tectonic. In particular, they are allowing us to model – with increasing sophistication – the material properties of architectural components. This volume, then, marks a particular moment in the history of architecture when the old oppositions between the digital and the tectonic has begun to collapse, and the digital is beginning to be used increasingly in the service of the tectonic. A new tectonics of the digital – a digital tectonics – has begun to emerge.” (Leach et al, 2004, p. 4-5).

In this view, the computer technology is seen as determining the development of tectonics to a large degree. While Leach et al. do ascribe the individual actor some importance, the focus is on the new technology and its ability to revolution the creation of tectonic architecture.

The discussion between whether it is the (computer) technology or the individual actor that primarily ensures a specific architecture can be seen as a continuation of a century-old discussion of whether it is the technology available that conditions the development of society or perhaps the society at a specific point in time that conditions the development of new technology (Castells, 1996).

The point of view of this investigation will maintain the double focus on the human individual and the technology available that is seen as the core of the tectonic tradition. The aspects of the tectonic practice that are investigated are therefore equally the individual actors – the architect and engineering consultants – and the digital technology as design tools. With this point of view that focuses on the computer’s ability but includes the actor using the computer as a design tool, the intention is to reach a nuanced understanding of what the computer can and cannot do in a collaborative design process; a broader understanding of the relationship between the actor and the design tool; and how the human actor and the computer programmes supplement each other.

Positioning the study in relation to other studies of tectonics

In the third group of writings on tectonics, there is a beginning body of knowledge about the relationship between the tectonic and the digital technology. The present research inscribes itself into this body of knowledge in that it focuses on the potentials of computer technology to the tectonic tradition. While there are other areas that investigate the computer in the architectural practice – for instance the field of Design Computing and Cognition (Chen, 2001) - the problem with these other approaches is that they are not concerned with which kind of architecture is being created and it is therefore difficult to relate to the tectonic practice of architecture. The selection of writings that this study draws on as its foundation to understand tectonics and to critically assess the relation between the computer and the tectonic practice is therefore the writings from the three groups already mentioned.

In several aspects, however, the study distinguishes itself from the existing three groups. This distinction arises for instance from the identification of a gap in the understanding of tectonics which is the case with the lack of understanding of the tectonic practice as opposed to the tectonic edifice. It also arises from a discrepancy in the basic ontological assumptions – about what reality is – which is the case in connection

to the digital tectonics where many of the writers begin their investigation by taking for granted that every architectural edifice is tectonic. Lastly it arises because of epistemological discrepancies - about what it is possible to know about reality – which is the case when this research insists on including an investigation of the actor in connection to the investigation of the computer's ability instead of looking at the computer technology in isolation.

To sum up on the problem identification that this introduction has presented; the three most important discrepancies between this research and the existing research (and thus also the contribution that this research intends to offer to the field) are listed:

Practice instead of architectural edifice

Most of the historical and traditional studies (Semper, 1851; Bötticher, 1844; Frampton, 1995) as well as most of the current studies of digital tectonics (Beesley and Seeböhm, 2000; Ham, 2003; Jabi, 2004; Gao, 2004; Liu and Lim, 2005a, 2005b) focus on tectonics as an edifice. By only addressing tectonics in terms of the resulting tectonic edifice, the practical side of tectonics has been neglected. This is contradictory when tectonics is seen in the context of the history where the ability to create tectonics grew from and depended on the master builder tradition where knowledge about the tectonic practice was passed on from one generation of architects to the next. In this tradition the intellectual discussion about the tectonic edifice was only secondary. In the contemporary understanding of tectonics – beginning with Bötticher and Semper – the practical understanding of how to create tectonics has to some degree been lost and replaced by a more theoretical understanding of the concept. The risk of this development is that the gap between theory and practice becomes too wide. The result which is already emerging is that tectonics is seen as something that belonged to the master builder era and is not possible to practice in a contemporary architectural context.

To avoid this risk of the tectonic practice falling into oblivion, this research will produce knowledge as to what the tectonic practice is, what enables and obstructs it and what role the (digital) design tool holds in this connection. This research thus leans on the notion (supported by Frascari, 1984; Beim, 2004; Leach et al., 2004; Leach, 2004; Cook, 2004; Turnbull, 2004) that tectonics is not only a character of the built architecture but also has to be a character of the practice that this architecture is developed from.

Tectonics – an exclusive term

Many authors of the current studies of digital tectonics (Gao, 2004; Liu and Lim, 2005a, 2005b) begin their discussion of what digital tectonics is by including all digital architecture in the investigation thereby implicitly addressing them all as tectonic. As it was argued in the beginning of the chapter, tectonics is in this research understood as a specific quality of architecture that consciously uses the technical and pragmatic concerns in architecture to develop an architectural expression. Tectonics as an exclusive term is stressed by the historical overview of the tectonic practice that argued that the understanding of and ability to create tectonics was largely forgotten during the late modernism and was only continued by a few architects. As such, the notion of tectonics as a character of every architectural project is rejected.

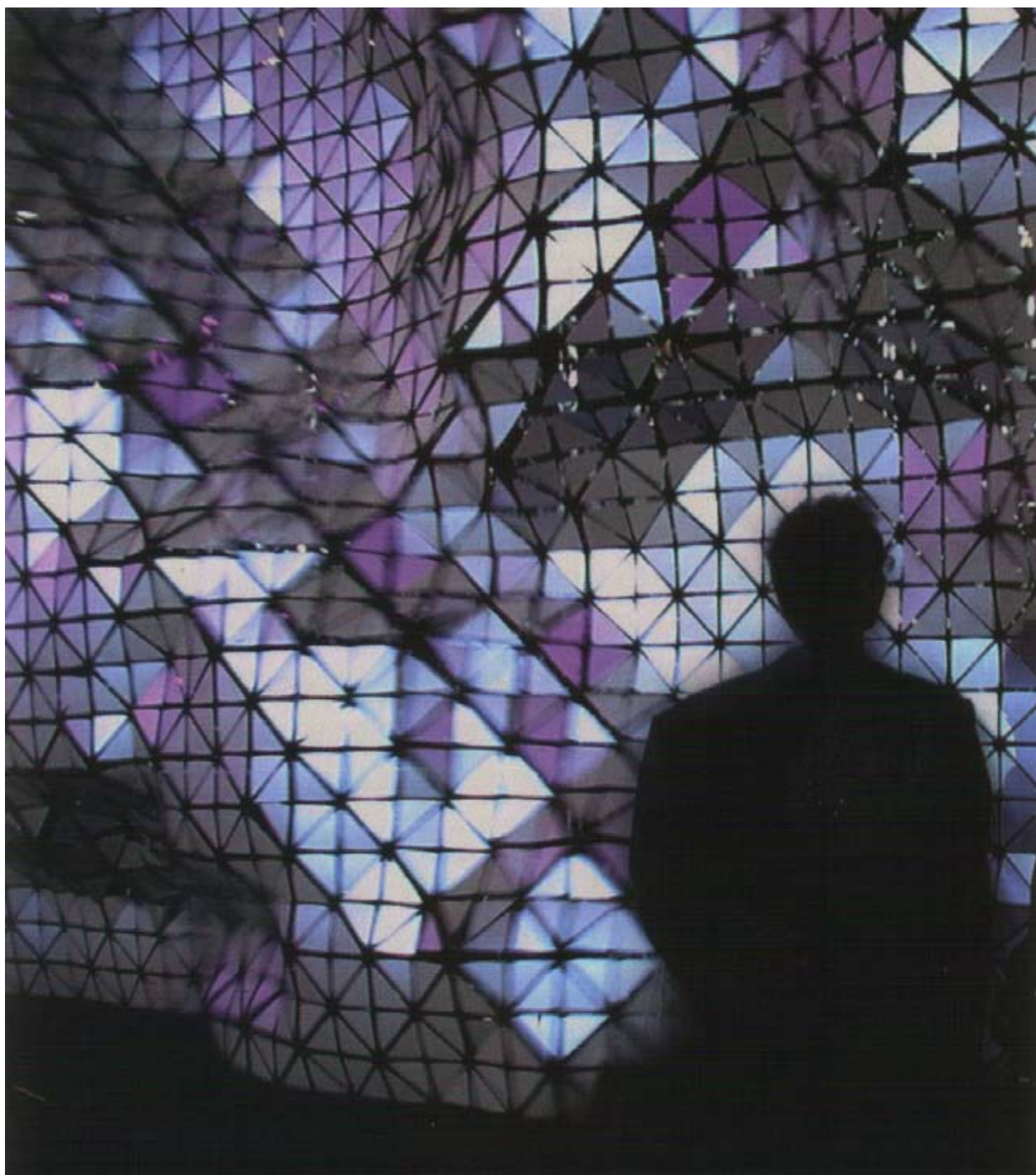


Figure 15: Segmented wall moved digitally. DeCoi.

If an understanding of the role of the computer technology in the creation of tectonics should be developed it is, with this understanding of tectonics, necessary to focus the study on tectonic architecture and not just any kind of architecture. This research therefore (supported by Bötticher, 1844; Frampton, 1995; Leach, 2004) views tectonics as an exclusive term and limits the investigation of the influence of the computer to practices that can be characterised as tectonic.

Actors and technology in a time span

Lastly, in the point of including both actors and technology in the study of the computer in the tectonic practice the study parts with all of the current studies in digital tectonic (Beesley and Seeböhm, 2000; Ham, 2003; Leach et al, 2004; Cook, 2004; Gao, 2004; Liu and Lim, 2005a, 2005b) which begin with the digital and does not seriously include the actor in the discussion of the new technology. The ability to create tectonics is, however, as Semper (1851), Beim (2004) and Frampton (1995) have argued, also influenced by the individual actor. The overly focus on technology holds the risk of limiting the discussion of tectonics to the development of new computer software while it is actually a conscious choice that the individual practitioner must make as well as try to get implemented in laws and practices.

This study will therefore focus on the computer technology in connection to tectonics (supported by the digital tectonics group of writers) but through the tectonic practice – thereby maintaining a point of view that includes not only the technology but also the individual actor in the practice (supported by Semper, 1851; Beim, 2004; Frampton, 1995). To be able to discuss the impact of the computer technology to the tectonic practice, two tectonic practices are compared – one where the computer technology is used and one where it is not.

RESEARCH OBJECTIVE AND RESEARCH QUESTION

Objective: to support a contemporary tectonic practice

The ultimate objective of this project is to enhance the ability of the practitioners to create tectonic architecture. Within the limits of the study, the objective of this research project is to enhance the understanding of how tectonics can be practiced in a contemporary – non-master builder – era. While not attempting to uncover every possible manner of conducting a tectonic practice, it is the aim to understand the characteristics of a tectonic practice. This understanding should uncover what enables and obstructs the tectonic practice. The focus is here internally on the collaboration between the architect and the engineer as well as on the design tools while external factors such as politics and economy are left out. Further the objective is to understand the relationship between the actor and the design tools available and thereby shedding light on to what extent the computer is – as the writings on digital tectonics argue – a potential to the tectonic practice.

This understanding should be able to serve as a model that can be referred to when discussing tectonics as a practice in the contemporary practice. Likewise the understanding should be able to be used as a strategy for creating tectonics in a contemporary context through the recognition of what enables and

obstructs the tectonic practice – it is as such the hope that actors involved with architecture and interested in creating tectonics will be able to apply the lessons learned to their own practices. And finally, the knowledge produced should also be able to be used in the development of computer programmes when the aim is (through the development of the design tool) to support a tectonic practice.

Research question

With this objective, it is possible to formulate the research question that is operational as well as a number of auxiliary questions that can shed light on the various aspects of the research question.

To what degree does the introduction of the computer programmes for computing, geometrical manipulation and visualisation to the collaboration between architects and consultants enable a tectonic practice?

Auxiliary questions

Theoretical background - the computer and the concept of tectonics

- What is the concept of tectonics?
- How is the concept of tectonics in the digital era understood?
- How can the introduction of computer programmes for computing, geometrical manipulation, visualisation, standardisation and rationalisation influence the practice of tectonics?

The tectonic practice: actor and design tool

- What characterises a tectonic practice?
- What enables and obstructs a tectonic practice?
- How did the individual actors - consultants and architects - involved in a design process and the design tools used enable or obstruct a tectonic practice in a pre-digital era?
- How do the individual actors - consultants and architects - involved in a design process and the design tools - including computer programmes for computing, geometrical manipulation and visualisation - enable or obstruct a tectonic practice in a digital era?
- What is the significance of the computer programmes – for computing, geometrical manipulation and visualisation - in creating tectonic architecture in comparison to other factors – actors and other tools – in the tectonic practice?

METHOD AND CONCEPTS



METHODOLOGY – TO CHOOSE A PATH

To investigate this research question, the research methodology is designed. The word method has its origins in Greek and means to choose a path. In the following, this chosen path is discussed and described.

Architecture as an academic field is still in the midst of developing its own research tradition (Mo, 2003, p. 10). In this vacuum, the challenge to architectural researchers – including the author – is to draw upon research traditions, methodology and philosophy of science from other fields while creating research relevant to architectural practitioners and researchers. The research methodology used in this project is therefore composed of a number of research methods.

The lack of tradition in architectural research results in a great degree of freedom in the choice of methodology. Roughly, science can be understood as three separate traditions with each their philosophy of science, each their view of what is relevant knowledge and each their methods of choice. Where natural sciences generally speaking deal with the actual, material world that can be measured, typically, social sciences are less interested in the actual, material world, focussing instead on how human beings perceive the world and interact with each other and the world according to said perception. The humanities in equally general terms are even less interested in the actual, material world but focus on understanding texts, art and other man-made objects.

A research project concerned with tectonics would often be positioned within the humanities (one example of this is Frampton (1995)) because it would focus on “reading” architectural edifices through a tectonic understanding of architecture. In the context of this study, this manner of approaching tectonics is used especially in the two chapters on the concept of tectonics. Likewise, the interpretation of the architectural projects created in the case studies can be positioned within the humanities. This project, however, is not solely interested in tectonics as a character of the built edifice, but as a character of the architectural practice, therefore, this approach is supplemented with other research traditions.

Elements of the study draw upon research traditions from the natural sciences. This is for instance the case when addressing, explaining and understanding the technical field that is investigated. Likewise, the focus on the computer as a design tool in the tectonic practice could have given rise to the use of a natural science model of research. Generally, this research tradition is the one most interested in the development and assessment of technology. In many ways the natural sciences would have been suitable to study tectonics as an architectural quality because tectonics, much more than other architectural movements, focuses on the material and technical aspects of architecture. The focus on the computer in this research project is, however, not on the computer as such, but on how, as a design tool, it obstructs or enables the tectonic practice. A typical natural science position would be adequate to evaluate the computer as a tool to enable the tectonic practice if there was already an understanding of how a design tool can enable a tectonic practice. Since there is not, the focus shifts from measuring the actual design tool to understanding how the tectonic practice is enabled or obstructed more generally.

Due to this focus and aim of the study, it is primarily positioned within the research tradition of social sciences. While the other research traditions have been used in connection with specific elements, the

concepts and methods are mostly borrowed from the social science tradition. The investigation of the computer as a design tool, then, is carried out not only by a focus on the tool itself, but by a focus on the use of the computer in the tectonic practice, attempting to understand the human beings using the design tool and understanding what enables and obstructs the creation of tectonics. Because the study focuses on the collaboration between the architect and the consultant, it also inscribes itself in a Mode 2 knowledge production, which Gibbons has described. Where Mode 1 is the traditional disciplinary-based research, Mode 2 is transdisciplinary and oriented towards the practical application.

"...Mode 2 knowledge production is transdisciplinary. It is characterized by a constant flow back and forth between the fundamental and the applied, between the theoretical and the practical ... Mode 2 is characterised by a shift away from the search for fundamental principles towards modes of enquiry oriented towards contextualised results." (Gibbons et al, 1999, p. 19)

The context here is the tectonic practice.

To return to Linn Mo (2003), one of her concerns is that architectural research will adapt the research traditions of other disciplines to such an extent that it ceases to be architectural research, becoming instead research in other disciplines. The present research project is probably not only interesting to architects, but to engineers and even computer programmers as well. A strong connection to the architectural field is maintained, however, through the focus on tectonic architecture. It is not just the ability to create any kind of architecture, but tectonics – architecture of a high quality with a connection between the technical aspects and the aesthetic aspects – that the knowledge produced focuses on. Therefore, it could be argued that while it leans mostly on methods borrowed from the social sciences, the research carried out in this thesis is primarily architectural.

Tectonics is equally a concept, built edifices and a certain practice

To answer the research questions, the study moves in two directions. Firstly a direction that spans from the concept of tectonics to the practice of tectonics and secondly a direction that spans from the pre-digital era to the digital era.

While it is too easy to glorify or reject the ability of the computer when studying tectonics as a theoretical concept or by looking at finished architectural projects, the understanding that is guiding this study is that it is not possible to understand the nuances in the impact of a tool in practice if not examining it in practice. This is based on the author's experiences in practice as well as Heidegger's saying, "We discover [a tool's] unusability, however, not by looking at it and establishing it and establishing its properties, but rather by the circumspection of the dealings in which we use it." (Heidegger, 1962, p. 102).

To discuss the use of the computer in a tectonic practice is therefore the main aim of this thesis. To be able to address the concept of tectonics, to be able to choose a tectonic case study to examine and to be able to analyse the empirical data from a tectonic point of view, a theoretical understanding of the concept of tectonics is, however, necessary. The simultaneous investigation into tectonics as a concept and as partic-

ular architectural practice is necessary in order to build the understanding of the tectonic practice on the solid ground of the tectonic tradition.

The time span is introduced because the research fundamentally is concerned with the move from a pre-digital era to the digital era and what this means to the tectonic tradition. Therefore, the study is carried out in both eras in order to be able to compare the two. This goes for both the concept of tectonics and the tectonic practice.

THE CONCEPT OF TECTONICS

The left column of the overview in figure 1 describes the starting point of the research - a literature review of the concept of tectonics exemplified by built architecture. The intention of the studies in this column is to unfold the concept of tectonics in order to specify the understanding of tectonics that is investigated as a tectonic practice. The chapters on tectonics in the pre-digital era and in the digital era will therefore be followed by a limitation that sharpens the focus already described in the introduction. In this section of the study, tectonics is approached through literature.

In the analysis of the concept of tectonics a general understanding of the concept is sought. While a critical analysis of the relevance of concept of tectonics is interesting in itself and could be worthy of a dissertation in its own right; it lies outside the scope of this investigation. The investigation into tectonics here is instrumental as a basis to discuss the ability of the computer to this manner of creating tectonics. The authors that are taken into consideration are therefore in the heart of the tectonic field and focuses on how to understand tectonics. With the borders for the investigation are drawn to contain only writers who are dedicated to

| | The concept of tectonics <small>Literature and architecture study</small> | The tectonic practice <small>Case study research</small> |
|-----------------|--|---|
| Pre-digital era | | |
| Digital era | | |

Figure 1: Overview of methodology

a tectonic understanding, there is still a wide range of understandings covered by the concept of tectonics.

The aim is to discuss the discrepancies between various writers or schools of tectonics and unfold the concept of tectonics by understanding the nuances in their definition of the concept. Three groups of writings – the historical, the traditional and the digital - described in the introduction are taken into account in the study. By focusing on these three groups, the investigation moves from a pre-digital era to a digital era.

In the historical writings the background of the modern understanding of the concept is investigated through the writings of Gottfried Semper and Carl Bötticher, whose focus varies slightly. In the traditional writings, the choice has fallen on two writers – Kenneth Frampton and Anne Beim. They represent each their school in a contemporary understanding of tectonics and therefore supplement each other well in the unfolding of the concept. In the understanding of tectonics as digital tectonics, it is the writings from Neil Leach that the concept is discussed from because he is the writer primarily interested in defining the concept.

The benefit - that outweighs the difficulties of including writings with a time-span of more than 150 years - is that it enables an understanding of the background of the tectonic tradition as well as it enables a well grounded discussion of the newest writings on tectonics. The method employed here is a hermeneutic reading of texts, meaning a reading that does not understand the writings as universal truths but truths that cannot be understood without understanding the context in which they are stated. The texts are all concerned with architecture and therefore the points of the texts are attempted exemplified by built examples.

The main research question concentrates on the concept of tectonics in the digital era and therefore the primary discussion of tectonics is also concentrated on the period where the computer has an impact on the tectonic practice. The investigation into the concept of tectonics is concluded with two models that operationalise the “degree” mentioned in the research question. The model is based on an analysis of the groups of writings on digital tectonics.

THE TECTONIC PRACTICE

The second column in the overview of the methodology in figure 1 is the study of the tectonic practice and thereby the focus of the study. The division between the columns of concept and practice should not be understood as absolutes but rather as a methodological division; the investigations into the concept of tectonics is the basis from which the case is chosen and the investigation of the tectonic practice feeds back into a new understanding of tectonics in the digital era.

The choice to investigate the tectonic practice rather than the tectonic artifice is – as argued in the intro-

duction - crucial because it breaks with the tradition of discussing tectonics only as quality of the architectural edifice.

Broadbent (1988) describes five stages in the design process; briefing, analysis, synthesis, evaluation and implementation. These are used to analyse the design process. It is expected that the ability to create tectonics is dependent on creating an understanding between the disciplines in the early stages of the design. Broadbent's model is used in the analysis of the tectonic practice with an awareness that the experience of a creative process is far from the image of linearity and well-defined stages that the model depicts. The advantage of the model is, however, that it offers a terminology of five stages that are identifiable in an architectural process. It should be mentioned that the investigation into the creation of tectonics is deliberately not named the tectonic method. A number of methods can lead to the creation of tectonics – instead the more open term practice is used.

The study of the tectonic practice is carried out as a case study research, which is,

"...an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2003, p.13).

The meeting between the digital medium and the tectonic tradition certainly is a contemporary phenomenon – this is not only true due to the recent introduction of the computer, it is also evident from the limited amount of writings on digital tectonics.

The specific method applied here is inspired by three publications; Robert K. Yin (1994), Robert E. Stake (1995) and Henriksen et al. (2004). All three publications deal with case studies from a qualitative rather than quantitative perspective. A quantitative approach could have been fruitful if the research objective, for instance, was to understand the general understanding of tectonics among architects. There is, however, a great difference in the everyday use of the term tectonics and the more elaborate writings on the theme. Because the aim here is to understand the concept of tectonics deeper than what a public vote would provide, it is difficult to move forward with a quantitative study. To respect and navigate in response to a concept under constant negotiation, the research method is therefore entirely qualitative.

The initial inspiration to the understanding and conduction of case studies is found in Yin's publication "Case Study Research – Design and Methods" which serves as a guide to the conduct of case studies. While Yin's publication does argue for the possibility of a single-case study, the examples in the publication are generally concerned with multiple-case studies. Therefore Yin is complemented by Stake who places great emphasis on the single case.

"Case study is the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances." (Stake, 1995, p. xi)

Also Bent Flyvbjerg (2006) supports this notion.

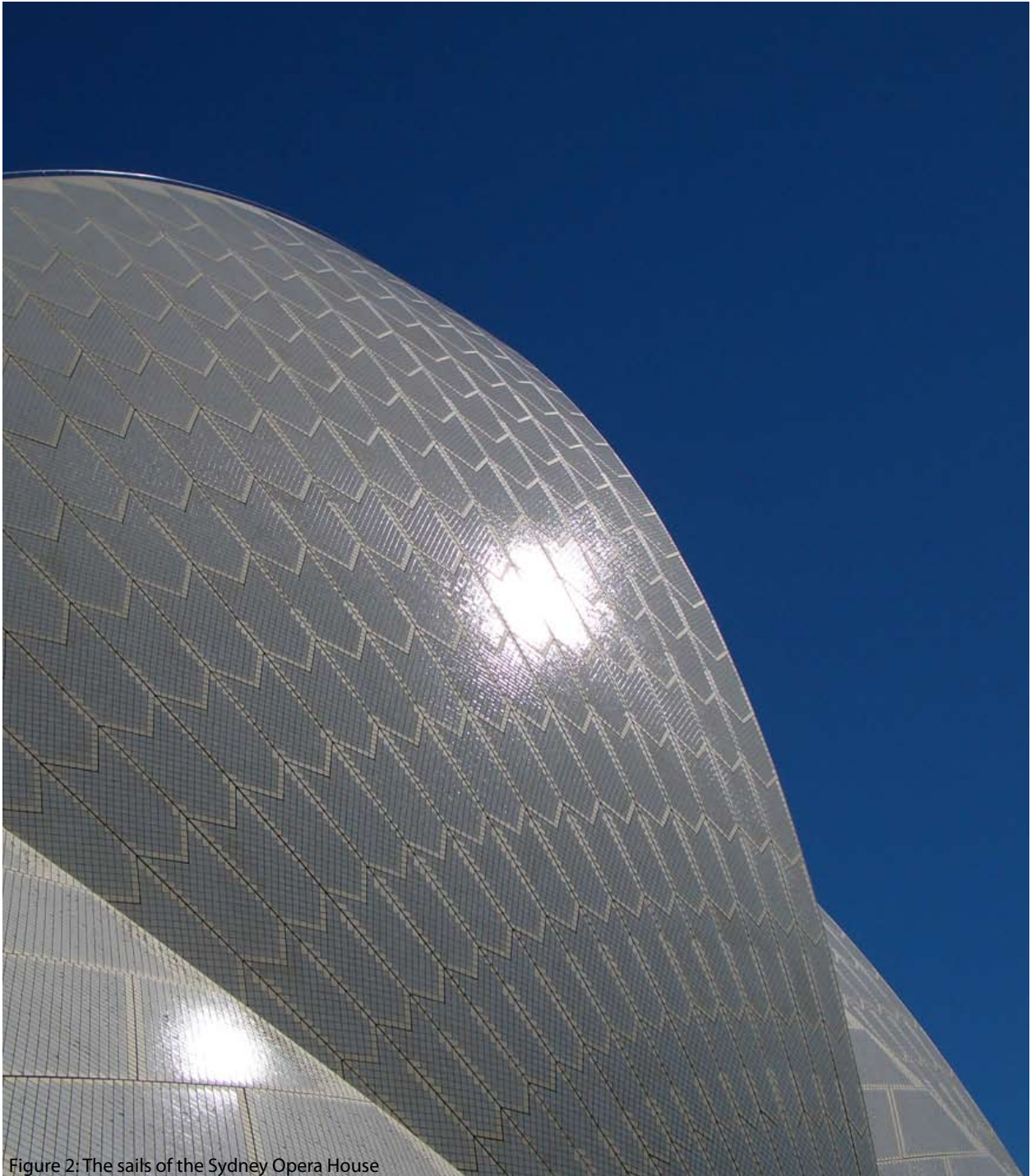


Figure 2: The sails of the Sydney Opera House

Lastly, Henriksen's examples of working with case studies are used. It is not a publication concerned with the case study method in particular but it does present several examples of case studies. In this connection it is used as an inspiration to the narrative writing style that can describe a change process (in this case the design process) instead of mapping a fixed point in time as Yin and Stake tend to do.

The case study is in this research intended to be both exploratory and explanatory (Yin, 1994) because the case study begins with a number of relatively open issues it is exploratory and when these during the course of the research are sharpened into two rival theories – the first being that the digital technology to a large degree is influencing the ability to create tectonics and the second that it only to a limited degree is the digital tools available that influences the ability – the case study is used in an explanatory manner.

Selecting the cases

Selecting cases is a difficult process. Stake (1995) recommends that the selection offers the opportunity to maximise what can be learned, knowing that time is limited - hence the cases that are selected should be accessible and willing subjects. In order to learn about the difference between the digital and the pre-digital era, an architectural project is sought that spans between the eras and thereby enables comparative case study research. With such a beginning point, Stake calls the case that is sought instrumental because it is with a specific intent that the case is studied and not for the sake of the case itself (in which case it would be intrinsic).

Instrumental cases are chosen due to its particular characteristics and in this case two demands to the case were crucial to the selection: (1) that it is a tectonic project and (2) that it spans from the pre-digital to the digital era.

Jørn Utzon and the Opera House project in Sydney match these criteria. In 1957-1965 Jørn Utzon and two teams of acoustic consultants designed the interior of the Minor Hall. The interior was never build due to Utzon leaving the project and a change of the brief. Instead the interiors were designed and build by a team of Australian architects. Today, however, problems with the acoustic quality and working conditions of the musicians have necessitated a refurbishment of the interior and Jørn Utzon was re-engaged to the project. In this project the technical field of specific interest will be the acoustic field and the actors investigated therefore the architects and the acoustic consultants.

The case matches the criteria firstly because Jørn Utzon is generally considered to be an architect who is interested in materiality and construction as a means to create an architectural expression. As Frampton remarks;

"Like the Norwegian architect Sverre Fehn, with whom he has collaborated on several occasions, Utzon's work is grounded in the tectonic line of the modern movement." (Frampton, 1995, p. 247).

Secondly the case spans from the pre-digital to the digital era – as such the second part of case is situated

within the context of the digital era not only because it is carried out in 2004 but primarily because the architect and engineers work with digital tools.

Other cases were considered to supplement or replace the Opera House case and a pilot case study was carried out. The intentions of the pilot case study were to test the methodological approach and the outcome was a realisation that the criteria from which the case was chosen was very important. As the pilot case the Hastings Cultural Centre by Tonkin, Zulaikha, Greer Architects in Sydney was used. Equal to the Opera House project it contained a close collaboration between architects and consultants and involved the use of highly sophisticated digital tools. During the preliminary study of the case it was, however, found that the Hastings project would prove extremely difficult to approach from a tectonic point of view because tectonics was far from the architectural intention. Rather than a holistic architectural solution, the aim of the collaboration in the Hastings project was to determine how the demands of every consultant could be fulfilled with the least infliction on the architectural solution. The Hastings project could have been used as a case study if the intention of present study had been to discuss general architectural practice as opposed to a tectonic practice. Since this is not the aim of the study, the case was not pursued. Instead the potential of the Opera House project's time span was exploited in order to be able to address the changing practice of tectonics.

Stake (1995) notes that it is not always possible to distinguish between intrinsic and instrumental cases, this is also evident in this case study research. The Opera House project is instrumental to the project goal because of the time-span and tectonic character of the project, but naturally it also holds a value of attraction (thereby being intrinsic) due to its iconic significance and Utzon's position in twentieth century architecture.

Data collection

The research is thus based on a diachronic architectural project that is investigated as two cases by attacking it at two different points in time. While there are many overlaps in sources relating to the cases and the connection of the cases as one continuous story, they will methodologically be treated as two cases in the data collection because the methods of collecting sources of evidence are different. The first part of the case (from 1957 to 1965) is referred to as the Minor Hall case while the second part of the case (from 1999 to 2005) is called the Opera Theatre case.

Yin (1994) proposes six sources of data: (1) documents (e.g. project proposals, interim reports, working papers etc.), (2) archival records (e.g. lists of names, personal records), (3) interviews, (4) direct observation, (5) participant-observation (where the researcher participates in what is observed) and (6) physical artefacts (e.g. models and drawings). While the sources of evidence in the Minor Hall case are primarily based on archival records supplemented by documents and physical artefacts, the source of the Opera Theatre case in addition includes interviews.

The publication about research interview by Steiner Kvale "Inter View – an introduction to the qualitative research interview" (1994) is the primary inspiration to the conduction of interviews because it places great

emphasis on the qualitative interview that is necessary to uncover the working methods of the professionals. Kvale distinguishes between two roles of the interviewer; the miner who is digging facts out of the ground and the traveller who attempts to get an overall impression of the world of the respondent. In this connection, the interviews are used in both ways because they are used to dig out facts to reconstruct the design process as well as they are used to ‘travel through’ to reveal the intentions of the actors. The type of interviews conducted were therefore equally focused interviews where the actors are asked about a theme because of their role as experts in this area (they were present in the design process) and open-ended interviews because the actors are asked more generally about their understanding of architecture, their professional approach and their use of technology in the design process.

As Kvale recommends, the interview-guides that were used to guide the interviews, does not directly consist of the research questions but more idiomatic questions that invites to a discussion of the theme (see the interviews in the appendix). Also in the analysis of the interviews, the methodology leans on Kvale who suggests a thematic coding where the interview material is examined for material on specific issues. The interview material was thus analysed through a coding reflecting the issues of the research: Actors, Collaboration, Technology/Design tools and Tectonics.

INITIATION OF THE CASE STUDY – PRACTICE:
BETWEEN ACTORS AND DESIGN TOOLS

An initial understanding of what is important to study in the cases is necessary to guide the data collection. Yin, Stake and Henriksen all recommend that one should not enter empty-handed to a case

| | The concept of tectonics <small>Literature and architecture study</small> | The tectonic practice <small>Case study research</small> | |
|-----------------|--|---|--------------|
| | | Actors | Design tools |
| Pre-digital era | | | |
| Digital era | | | |

Figure 3: Overview of methodology with issues specified

study but their understanding of how closed or open a theoretical approach one should have when entering the case study varies – Yin argues for a strict research question, Henriksen for an open approach. In between these positions, Stake proposes working from a number of issues. This method seems suitable since the case was already chosen due to its ability to tell something about actors and the use of design tool. These aspects were therefore the primary focus points in the case study as it is indicated in figure 3. Actors and design tools are used as issues as Stake proposes.

“Hypotheses and goal statements sharpen the focus, minimizing the interest in the situation and circumstance. I choose to use issues as conceptual structure – and issue questions as my primary research question – in order to force attention to complexity and contextuality.” (Stake, 1995, p. 16).

Actors: collaboration between practitioners

The reason to investigate the tectonic practice through case study research in the first place was the condition that a few of the actors working in the realm of praxis already possessed an ability to create tectonics – how else would it ever occur? The collaboration naturally depends on a long list of actors but within the limits of the study, the ones focused upon are the engineers and the architects. While the professional distance between architects and engineers from a theoretical point of view seems long, specific professional actors clearly possess methods to overcome this distance and thereby enable architects to work creatively with technical aspects and engineers to work rationally with aesthetic matters.

Design tools: Digital technology and other tools

The other issue in focus was the new technology. The digital technology becomes a design tool in line with other tools in the design process – models, drawings etc. The tools are called design tools if they assist any of the five stages of the design process described by Broadbent for instance by visualising the architectural scheme in the synthesis stage or assisting the evaluation of it in the evaluation stage. It was supposed that the use of the technologies assisted the design process and the collaboration between the professionals as many writers have argued – among them the writers on digital tectonics - but to what extent this actually assisted the creation of tectonics and not just made designing quicker and more efficient was more difficult to understand without direct studies of the tectonic practice.

These two issues were therefore the focus of the case study research described in the chapter The Minor Hall case and the chapter The Opera Theatre Case.

Actor and practice – the individual conditioned by structure

With these issues identified, the collection of data in the case studies began. However, in order to make sense of the data collected an understanding of practice was needed.

Fundamentally there are three ways of understanding practice; primarily as the result of free actions of individuals, primarily as a structure in which the individual acts on laws and rules and lastly, as actions of the individual relative to a structure (Østerberg, 2005).

The first understanding is often called individualism and argues that everything can be explained from the actions of individuals; the methodological focus is therefore on the individual as an “actor” who acts in the world based on intentions and individual reasons (for instance Sartre understands the world like this (Lübcke, 2002)). In connection to the tectonic practice, the focus would therefore be on the individual architect or engineer and the ability to create tectonics would rest on the individual actor regardless of the conditions outside the process. This understanding of practice is predominant in architectural discourse which can be seen from the many architectural monographs on architects as well as the understanding of the architect as a lone genius.

The second understanding, which is often called structuralism, is in complete opposition to this understanding. As Levi-Strauss argues, the individual is limited by the structure of the world (formal and informal laws, classes and economic structures) – for instance the peasant cannot become king despite all his efforts. The individual thus does not act according to own desires and intentions but as it is possible within the structure. The individual freedom is in this model very limited. Levi-Strauss takes the identification of structures to account for that social science only needs to be concerned with the structures and not the individual (Østerberg, 2005). In connection to the tectonic practice, the architect and the engineer would fulfil their roles according to their professions but would not have the ability to influence them from their own interests. This model of explanation was immediately rejected because it in this understanding would only be the contractual relationship between the architects and engineers, building codes and organisation of the building industry that would determine whether it would be possible to create tectonics. As it was described in the introduction this seems unlikely. Despite the changing conditions of the architectural practice from a master-builder era to the post-industrial era it was possible for a number of architects to create tectonics in the industrial era. The changing structure wherein the actors had to act did then not completely inhibit the creation of tectonics - the actor therefore had to possess some ability to influence his or her situation.

The third understanding of practice positions itself in the middle of these two extremes and can be called a mediating position because it attempts to combine individualism and structuralism. This is done by arguing that the structure of society conditions how the individual actor acts, but that the individual actor also has the ability to change the structure. This is possible because the structure of the world is not seen as something stable and external to the actors as it is in structuralism. In these theories the structure is rather perceived as created and maintained through the actions of the individuals. The role of the king is not a natural given condition. Rather, it is something that is constantly negotiated; the population might opt for a republic, thus undermining the structure of people versus royalty. On a smaller scale, a person in a group does not have authority per se; a position in a group is constantly negotiated and maintained by the group as well as the individual.

Like the king, all other roles in society are equally defined by the structure and the individual. In connection with this specific study, it is the role of the architect and the engineer that is interesting. While these professional roles are created through the education and practice of each field, they are also created and maintained by each individual actor. While one would expect a certain behaviour from an engineer versus an

architect due to their professional background, the distinction between the professional fields is not external but created and maintained by the individuals. By understanding the structure in this manner it becomes fluid and possible for the actors to define their own professional fields. Tectonics as an architectural movement in a post-master-builder era is interesting because it relies on the actors to work across the professional boundaries. In connection with the tectonic practice this relational point of view would mean that the ability to create tectonics is conditioned to a large degree by the structure of professions and the building industry in general, but that the individual actor would still be able to influence the condition.

This research project began with ambivalence between the individualistic and mediating understanding of practice, while the structuralistic one could easily be dismissed. One model along the individualistic line of thinking and one along the mediating line of thinking was therefore introduced. The model along the first line was Henriksen's method for the study of organisational change (Henriksen et al, 2004). This method places great emphasis on the individual actor's values, logic, language and general understanding of his or her reality. The model along the mediating line drew on Bruno Latour (1988) as well as Pierre Bourdieu (1977, 2005) despite the differences in their thinking. As the research developed it became clear that the individualistic model was not adequate to understand the problem at hand because it lacked the ability to explain why the individual was not able to support a tectonic practice. The relational model of explanation – inspired by Latour and Bourdieu – is therefore used to understand the practice of tectonics.

Latour's version of the actor-network theory is interesting because it encompasses an understanding of technology. Latour argues that society cannot be understood without including technology into a power perspective.

"The duplicity we have to understand is no longer in Princes and Popes who break their word, but in the simultaneous appeal to human and non-human allies. To the age-old passions, treacheries and stupidity of men or women, we have to add the obstinacy, the cunning, the strength of electrons, microbes, atoms, computers, missiles." (Latour, 1988, p. 29).

However, Latour's writings are very concerned with power struggles and sees technology primarily as an instrument in these struggles. In an attempt to apply Latour's frame of thinking to the interaction between architect, consultant and design tools, several obstacles arose. The collaboration is – with Latour's eyes – seen as a struggle between the actors in order to gain power. While there were plenty of struggles between the actors involved, a simple gain of power did not seem sufficient to explain encounters between the actors.

In one instance, for example, one of the engineers had difficulties in supporting the design development in the Minor Hall case. If the occurrence is explained with recourse to Latour, the engineer is ascribed murky intentions and as having a hidden agenda that makes it beneficial for him not to collaborate. The collaboration of the architect or the engineer was difficult to understand from this perspective because both professionals fundamentally gained more from collaborating than from not collaborating. Likewise, the data material reflected no hidden agendas. On the contrary, it seemed that all actors were doing their best to

collaborate, but at times they failed – not because they were not trying, but for reasons that could not be explained from Latour's perspective.

In addition, Latour's thoughts on technology present it solely as an instrument to gain power. In this perspective the use of design tools is seen as controlled by the architects and engineers in order to gain power. This manner of assessing technology does not question the actual technology, but only assess the actor's use of these. While Latour could be used to analyse the case studies, it would therefore be difficult to come closer to a real understanding of the impact of the computer as a design tool.

Latour's direction in this mediating position was therefore rejected as an explanatory model for the tectonic practice, and an understanding that attempts to explain the actions of the actors more closely and encompassing the use of tools in the design process was needed instead. Such a model of explanation is offered by Bourdieu and Heidegger who attempt to understand the actions of an actor not only from the present situation but from a range of conditions already present in the actor – such as upbringing and profession. The research does not follow a complete Bourdieuan structure, but uses a number of his concepts such as field, habitus and capital.

A field, according to Bourdieu, is a socially constructed arena – this can be the football playing club, the family or – as in this research – collaborate practices in which different actors collaborate to create an architectural project. A field can as such be said to be a more or less well-defined portion of reality in which the actor has a specific role. The notion of field is important in the sense that the same actor can hold different positions and thereby change roles according to which field he or she participates. For instance, an actor who is unemployed and therefore at the bottom of the social ladder can be the principle coach in his son's football club and thus in this connection – within a different field – be an important and powerful actor. The field thus influences the actors as well as the actors influence the field. The case of the tectonic practice is particular in the sense that it cannot be understood only in terms of one field. The actors, architects and engineers, who participate in the project creates a field among them as collaborators but they are also part of their professional field – this conflict is interesting as an explanatory frame to the tectonic practice.

Habitus is ways of acting that the actor picks up through childhood, through professional training as well as participating in new fields. Within each field there is a set of habitus that ensures the "production of a commonsense world endowed with the objectivity secured by consensus on the meaning (sens) of practices and the world..." (Bourdieu, 1977, p. 80). This means that within each field – for instance the field of an architectural practice or the field of an engineering practice – there will exist a more or less coherent understanding of 'how things are done'. In a collaborative process, the habitus of various fields coexists and it seems that it can be expected that in order to create tectonics, a common habitus or at least an understanding of other habitus'es must occur.

Movements in the structure of the field can happen through the actor's acquisition or loss of capital. Capital, in Bourdieu's understanding can either be actual economic capital or symbolic capital (prestige

and honour). The last kind of capital is less easy to assess but never the less has a great impact on the weight of the words of an actor. A specific case of symbolic capital is the cultural capital that has to do with the value other actors ascribe to a certain profession – for instance a professor in history is not necessarily more wealthy than a carpenter but his profession is more prestigious and he therefore possess more cultural capital. The particular aspect of cultural capital is that the value of it can only be created and maintained through a mutual understanding among the actors in the field. Garry Stevens has for instance investigated why architects who teach at universities fails to built up research communities and found that even among architects working in the education system it was only design and the realisation of buildings that counted as cultural capital – not the publication of research papers (Stevens, 1998). In the tectonic case cultural capital is interesting in the sense that in a general understanding, the capital of the fields of architecture and engineering would be different. At the same time it seems fair to expect that the creation of tectonics depends on a mutual understanding of capital among the actors – if they do not agree on what are the success criteria of the product how can they collaborate to create it? This is, however, difficult given that the actors are also parts of other fields which have quite different demands for the rewarding of cultural capital. This tension between the fields understood individually as separate professions in contrast to the fields seen as sharing a common understanding of capital or sense of goal of the architectural project, is seen as an explanatory frame to the tectonic practice.

In the understanding of the tectonic practice, the concept of field, habitus and capital thus serve as an analytical frame to enable an analysis of the actors as individuals. Likewise this frame of thinking serves as a way to understand how these individuals collaborate in the tectonic practice by creating a shared fields, a common habitus and a shared understanding of capital – i.e. a common understanding of what the success criteria of the architectural project is.

Design tools: Artefacts as an extension of body and mind

The second issue that is investigated through the case studies is how the digital technologies affect the tectonic practice. There is a close link between the analysis of the actor and the analysis of the design tools. Not only is it the actors that introduce the design tools to the design process, it is also the actors that decides how these tools should be used. In the analysis of the case the analysis of the actor and the design tools are therefore intertwined. Methodologically, however, there is a difference between the two aspects because the system of concepts necessary to grasp and explain the actor and the design tool are different.

In the tectonic tradition technological artefacts as an extension of the mind and body has always played a role as mentioned in the introduction. In the case of the digital media, it is not only directly the material processing that is affected but also the design process – increasingly separated from physical materials – that is affected. The digital technology becomes a design tool in the design process.

To understand how the digital technology is used, it is necessary with an understanding that is able to grasp the difference between using various artefacts. In his study of the architectural profession, Donald Schön (1983) commented that the architect language of design is composed of that he talks through words (verbal) and drawing (non-verbal) equally. And in connection to tectonics Marco Frascari (1984)

describes how Carlo Scarpa uses the drawings to jump between levels of abstractions in order to ensure a consistency between detail and whole.

No-one has, however, developed concepts as generally applicable and adequate on the use of artefacts as Martin Heidegger. Like Bourdieu he is interested in the practical knowledge of the world (Kemper, 2001). He argues that objects that are well suited to what they are being used for becomes an extension of the body to an extent where one does not think about the tool anymore. This he exemplifies by the use of a hammer where the hammer as an object recedes into the background of one's mind when using it. The act of hammering thus does not entail that one is actually thinking about the hammer. On the contrary, the attention is directed to the task one is attempting to accomplish. This state Heidegger calls ready-to-hand. In connection to the tectonic practice, a well-suited artefact (digital or not) would be ready-to-hand and thereby enables the actors to concentrate on creating tectonic architecture.

Heidegger's notion of artefacts is in this study taken quite broadly – not only are actual artefacts (such as pencils, clay, and physical models) considered as artefacts but also more specific uses of these artefacts will be considered as separate artefacts as long as they are used in separate contexts in the design development. For instance the computer is not only seen as one artefact but as several tools depending on which software and the specific context that it is used within.

Heidegger maintains a very physical understanding of the artefacts that he is talking about – the hammer etc – and explains how the artefacts becomes an extension of the body. In connection to the tectonic practice, the same ready-to-hand concept will be used to talk about tools that are less physical – such as the computer – in the connection that they serve as an extension of the mind. In this connection the terms from Heidegger serves as a good frame to discuss the artefacts as design tools.

With the hammer as an example, Heidegger in 1962 developed a nuanced system of concepts to describe the degrees to which a tool is ready-to-hand or not. Only when the object stops fulfilling its function we become aware of the tool as an object. Only in that moment we become aware of the tool and an awareness of how well it fulfilled its purpose before being broken can occur, "Paradoxically enough, objects become visible as ready-to-hand primarily when they become unhandy in various ways..." (Mulhall, 1996, p. 49).

The state of the artefacts when they are no longer ready-to-hand because they stop being instrumental to what a person is doing, they are in Heideggerian terminology present-to-hand.

Heidegger exemplifies this state of the artefacts when they are no longer ready-to-hand because they stop being instrumental in three ways. When a tool is damaged, when the hammer for instance is broken, it becomes immediately visible that the tool is no longer usable in its intended manner. This state of the tool Heidegger calls conspicuous, "...this implies that what cannot be used just lies there..." (Heidegger, 1962, p. 102-103). The second manner of being unready-to-hand is when a tool is known to exist but is out of reach – for instance if the hammer is gone from its place in the tool box, it is no longer an extension of the

| | The concept of tectonics <small>Literature and architecture study</small> | The tectonic practice <small>Case study research</small> | |
|-----------------|--|---|--------------|
| | | Actors | Design tools |
| Pre-digital era | The concept of tectonics (ch. 3) | The Minor Hall case (ch. 5) | |
| Digital era | The concept of tectonics in the digital era (ch. 4) | The Minor Hall case (ch. 6) | |

Figure 4: Overview of methodology with issues specified

body and mind. If the rest of the tools in the tool box cannot be used for the task, they present themselves as obtrusive, “we also find things which are missing – which not only are not ‘handy’ but are not ‘to hand’ at all.” (Heidegger, 1962, p. 103). The last manner a tool can be unready-to-hand is to be obstinate in that it is not assisting in solving the task at hand. For instance if the hammer is too big for the nail that needs to be hammered into the wall, it does not assist but rather obstruct the work.

“...the un-ready-to-hand can be encountered not only in the sense of that which is unusable or simply missing, but as something un-ready-to-hand which is not missing at all and not unusable, but which ‘stands in the way’ of our concern....Anything which is un-ready-to-hand in this way is disturbing to us, and enables us to see the obstinacy of that with which we must concern ourselves in the first instance before we do anything else.” (Heidegger, 1962, p. 103).

These concepts will in the case study of the tectonic practice be used to describe to what degree the design tools are adequate to the task of creating tectonics. The best design tool is the artefact that is ready-to-hand, recedes into the background of ones mind and can assist the actors in creating tectonic architecture. The worst design tool, on the other hand, is the tool that constantly springs into the front of ones consciousness in any of the three manners described by Heidegger and where the actor is constantly aware of using it. The digital technology as a design tool will therefore be compared to the design tools in the pre-digital era with respect to its ability to serve as a ready-to-hand artefact.

CONCLUSION

In this chapter the methodology of the research is outlined and discussed. It was described earlier how architecture does not have a research tradition of its own, and how the research therefore leans on research traditions from other fields. The natural sciences are used to discuss the technical field investigated, and the humanities to discuss the concept of tectonics as well as the architectural results of the case studies. Primarily, however, the research tradition that is borrowed into is that of the social sciences because it is the interaction, negotiation between professional fields and the use of design tools that is in focus.

The primary method of research is comparative case study research between a tectonic practice in the pre-digital era and one in the digital era. In order to focus the study, two issues to discuss and compare in the two eras are introduced: the actors and the design tools.

The actors that are particularly interesting in this study are the engineers and the architects. In order to create tectonics in a post-master-builder era it is necessary for these professions to collaborate. The methodology from Bourdieu provides a conceptual basis to address the tectonic practice as the meeting between two actors from each their professional field, with each their professional habitus, each their understanding of capital and hence each their initial understanding of the aim of a shared project. The tectonic practice is understood conceptually as individuals creating a shared field, a common habitus and a shared understanding of capital – i.e. a common understanding of what the success criteria of the architectural project are. Furthermore the tectonic practice entails the use of design tools. In order to address the adequateness of the design tools, Heidegger's notion of ready-to-hand versus present-to-hand are used.

These concepts can be used to analyse and understand the actions of each actor, the interaction between the professionals and to discuss the role of the design tools versus the actors. In a broader perspective, then, the intention of implementing this particular methodology is to provide a toolbox to answer the research questions by handling the actors and the design tools; issues that are seen as important to the tectonic practice.

READER'S GUIDE

The current research project entails elements from a number of fields. Most likely, then, different readers will be searching for different elements. In consideration of this, the following reader's guide presents a few general remarks on how the project is written, which parts can be read separately, why some terms are used and an overall description of the various parts of the study.

The project is written primarily with architects as the audience. While parts of the study would be of interest to acousticians, the technical description of this field is held at a minimum that will allow laypeople to follow

the argument. The study discusses the introduction of the computer but due to the general aim of the study, the specific technical descriptions of programmes and computing methods has been held at a minimum during the project as such. One exception is, however, an article analysing the acoustician's simulation tools that can be found in the appendix.

While the study naturally has an argument that runs along the whole project, some parts can be read separately from the rest. This primarily goes for the case chapters, The Minor Hall case and The Opera Theatre case. The chapters on tectonics, The Concept of Tectonics, can be read as an introduction to the term and the middle part of the following chapter, The Concept of Tectonics in the Digital Era, can likewise be read as an introduction to the concept of digital tectonics.

Throughout the research project terms such as actors and habitus are used. The term actor could almost be replaced by the more common word practitioner. Likewise, the term habitus could almost be replaced by the more common word approach. The risk of using the terms actors and habitus is to disturb the storytelling in the case studies, whereas the risk of replacing them is that they become less precise. The terms are therefore maintained to ensure precision and because these terms refer to a specific theoretical background.

The bibliography and references conforms to the Harvard standard (Quote, Unquote - The Harvard Style of Referencing Published Material, 1998).

The study begins by unfolding the concept of tectonics in the pre-digital and digital era. The investigation of the concept of tectonics in the pre-digital era is found in chapter three. The chapter analyses the understanding of tectonics through the writings of three of the heavyweight theorists; Gottfried Semper, Carl Bötticher, Kenneth Frampton and also leans heavily on Anne Beim's newer writings. The intention is not to choose one understanding of tectonics over another, but to identify a number of approaches that all fall under the concept of tectonics. The aim of this investigation, then, is to understand the nuances of the concept, describe the perimeter of the study in precise terms, become able to use the concept in connection with architectural projects and provide a background for discussing the possible impact of the computer on the tectonic tradition.

The investigation of the concept of tectonics in the digital era is found in chapter four, where the focus is a discussion of the concept of digital tectonics. The writings on digital tectonics are highly inspired by the introduction of the computer in the architectural practice. The first investigation is therefore concerned with whether the contemporary computer programmes touch upon the concept of tectonics as it was identified in the previous chapter. Secondly, the concept digital tectonics is analysed. The aim of this chapter is to discuss what the implicit understanding of tectonics is in contemporary writings. Through a critical assessment of the concept of digital tectonics, it is attempted to create leverage to develop a broader understanding of the tectonic practice and its relation to (digital) design tools. The end of the chapter will therefore propose competing or complementary models to understand this relationship. These models attempt

to describe the tectonic practice through the human actor, the collaborating professional fields and the relation of these to design tools.

With the ballast of an understanding of tectonics and an initial understanding of the relation between tectonics and the design tool, the two following chapters take the investigation of the design tools into an actual tectonic practice situation by following design processes and their dependency on design tools. The investigation will focus equally on the actors and the design tools in the practice. The aim of the case study research is to expose to which degree the individual actor (consultants and architects) and the various design tools (including computers) can be seen as enabling or obstructing the tectonic practice.

The case study chosen for investigation is the Sydney Opera House with a focus on the design development of the acoustic auditorium Minor Hall later called the Opera Theatre. The first case describes the design development a pre-digital era and discusses the role of the actors and design tools. The second case describes the refurbishment project of the same hall in a contemporary context where new digital design tools have been introduced into the process.

Chapter seven collects the observations in the two cases. The comparison will focus firstly on the tectonic approach in the two projects. Secondly, the design developments of the two projects are compared stage by stage. In this comparison the aim of the projects as well as the role of the design tools and the actors are discussed intermittently. The comparison concludes with separate analyses of the role of the actor and the role of the design tools. The aim of this comparison is to learn more about the tectonic practice in general, and about the use of design tools in particular. Thereby this case comparison becomes the foundation for discussing the potential of the computer in connection to the tectonic practice.

Chapter eight is the conclusive chapter. Firstly, a summary will describe the research project. Next, an overall conclusion finalises the investigation by discussing the role of the computer as a design tool in the tectonic practice. The findings of the research are summarised and discussed in terms of reliability and validity. Lastly the implications of the study are discussed in terms of the perspectives of the future tectonic practice.

In the Appendix an article analysing the computer simulation programmes used by acousticians, the transcribed interviews, references and illustration credits can be found.

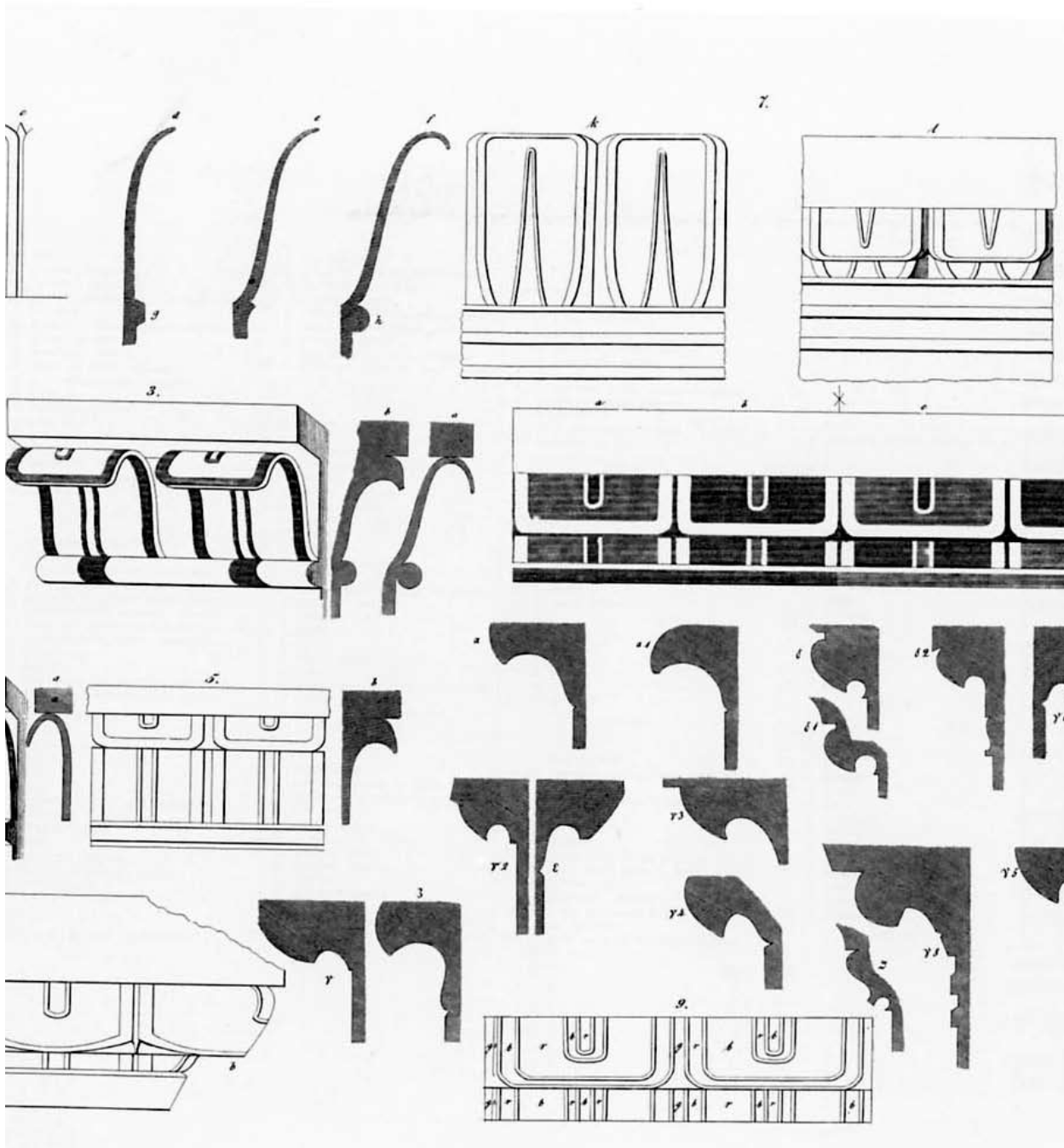


Figure 1: Analysis of the Greek ornamentation. Illustration from Carl Bötticher, Die Tektonik der Hellenen

THE CONCEPT OF TECTONICS

To be able to understand the impact of the computer on the tectonic tradition, an understanding of the meaning of the concept of tectonics is necessary. The aim of this section is thus to analyse the concept of tectonics in the historical and traditional writings before the computer had an impact on the term. In the subsequent chapter this understanding will be used as a background for dissecting the understanding of the concept of tectonics held by writers today.

The term tectonic is closely connected to the professional title of the architect because the word architect is a contraction of *archi* and *tekton*, *archi* meaning master and the Greek *tekton* meaning carpenter or builder. The Greek *tikto* refers to to produce and describes a simultaneous existence of art and technology. The term tectonic thus refers to objects without distinguishing between the fields of art and technology, and also to the process of creating these objects.

The term tectonics has its roots in the Greek conception of the creation of artisan objects, and it was only later used in connection with architecture. Carl Bötticher and Gottfried Semper were the first writers to use tectonics as a term in recent architectural history. The writings on tectonics came to be very influential, in part because most architectural publications before Bötticher and Semper were handbooks in the creation of various styles and orders of architecture. Bötticher (1844, 1846) introduced the distinction between the structural core-form and the decorative art-form. With these concepts he argued that tectonics in architecture is the meaningful relationship between the core-form and the art-form of a building, thereby calling for architecture where the façade articulated the structural principles instead of being conceived as separate concerns. Semper can rightly be called the father of the modern perception of tectonics. He based his understanding of architecture on the study of primitive building traditions and came to the conclusion that the knot was the beginning of enclosures, and the woven enclosure of the tent was the beginning of architecture. This understanding was in stark contrast to Laugier's notion of the primitive hut as an imitation of nature (1753). Instead, Semper introduced four elements of architecture; earthwork, hearth, roof and enclosure (Semper, 1844, 1860), and he argued that these elements were derived from each their material and that each had their technique. The human desire to create patterns and pictures to order their world was the primary reason behind architecture but the tectonic relation between material, function and technique influenced the expression.

During the Modernist era the writings on tectonics were criticised. The architectural theorist Alois Riegl (Mallgrave, 1989) argued that tectonics neglected the human being by understanding the architectural expression as being determined by materials – a wrongful interpretation of Semper's intention. A few writers nevertheless remained interested in tectonics. Eduard Sekler (1965) distinguished between the concepts of structure, construction and tectonics. Structure was a principle (for instance the principle of post and lintel). This principle could be executed in various materials, thereby resulting in many possible constructions of the same principle. According to Sekler, structure and construction were part of the domain of the engineer. In contrast, tectonics was the domain of the architect and focused on expressing the structure and construction through detailing and joints. This decorative understanding of tectonics must be said to be a much reduced version of the concept of tectonics that Semper and Bötticher described. Carlos Vallhonrat (1988, 2000) argued that great works of architecture could be seen as the

Figure 2-3: Villa Rotunda by Palladio and fire station by Zaha Hadid. Despite their differences both buildings are consistent in each their choice of details, construction, plan and facades



conscious expression of structure and construction, while others merely copied the former. As an example, Louis Kahn's double arches (holes) were an architectural answer to building in an earthquake zone, but have often been copied to areas without earthquakes.

Vittorio Gregotti (1983) had a more bodily approach to tectonics than Sekler and Vallhonrat. He argued that a column should not first and foremost be understood as a support, but as a representation of the body. The choice of structure and construction was therefore not only the domain of the engineer. Gregotti understood the detail in architecture as the point from which the bodily experience of architecture should be created. Likewise, Marco Frascari (1984) argued for the importance of the joint. He called his essay the-tell-the-tale-detail thereby pointing to the role of the detail (formal as well as structural) as the conveyer of meaning in architecture. Frascari was concerned with the impact of the industrial production to the detail. Karl Christiansen (1994) was likewise concerned with the contemporary architecture and argued that the buildings that we build were not the ones we would see. The actual construction, often in prefabricated concrete, was concealed behind plasterboards and façade covering. Christensen argued that architects should learn to take advantage of the expressive potentials of the new building materials instead of concealing them.

Kenneth Frampton (1982, 1990, 1995) is the most influential writer on tectonics in recent times. Frampton's interest in tectonics began from a concern with the tabula rasa method of the Modernists. He used Semper's notion of tectonics as a starting point for critically assessing Modernist architecture that ignored the context (Frampton, 1982, 1990). Later (1995), he described the sporadic continuation of the tectonic tradition and

defined tectonics as the poetics of construction. In her thesis "Tectonic Visions in architecture– Investigations into practices and theories of building construction. Six case studies from the 20th century" from 1999 and in the publication "Tectonic Visions in Architecture" from 2004 that developed and elaborated the thesis, Anne Beim continued Frascari's concern with the industrial production of architecture. Beim argued that architects had a continuing ability to create tectonics in the new context and demonstrated this through the works of six architects that were inspired by the industrial materials, technology and principles.

The aim here is not to choose one definition or understanding of tectonics over another. Rather, the aim is to unfold the concept by identifying a number of approaches that all fall under the concept of tectonics in order to be able to discuss the impact of the computer on each of these approaches.

Due to this aim, the writings that are analysed in the first section on the concept of tectonics fall into two categories – the historical writings from Carl Bötticher and Gottfried Semper and Kenneth Frampton, who is the primary writer on tectonics in a contemporary context, but who also focuses on the tectonic tradition by not including the computer into his investigation of the concept. Also the writer Anne Beim, who is concerned with tectonics and technology, is touched upon in this section as the writer closest to a concern with tectonics as a practice.

Tectonics – creating oases of order and materiality

"Finally, it will be a delight to talk of ARCHITECTURE after so many grain-stores, workshops, machines and sky-scrappers. ARCHITECTURE is a thing of art, a phenomenon of the emotions, lying outside questions of construction and beyond them. The purpose of construction is TO MAKE THINGS HOLD TOGETHER; of architecture TO MOVE US." (Le Corbusier, 1970, p.23).

What binds the writings of tectonics as an architectural movement together, is their understanding of architecture as more than a rational, sheltering commodity and more than an aesthetic choice between styles. The common understanding of the role of architecture found in the writings on the concept of tectonics is the cultural role of architecture that goes beyond the single piece of built architecture.

As Gaston Bachelard argues (1965), dreams, fears and desires are constantly present in architecture and walls, moats and fences hold another meaning than bridges, windows and doors. Architecture is therefore first and foremost an instrument to create a human experience and only secondly rational construction and structure - architecture has a symbolic value that is as important as its sheltering function. The experience of architecture in our everyday life has little to do with rationality; rather we experience it as phenomena through a filter of emotions and earlier experiences. With a point of view in where architecture is seen as more than merely a rational endeavour, the writings on tectonics often take the form of defence of the symbolic aspects, artistic view and other seemingly irrational sides of architecture. The writings argue that the irrationality in architecture plays a significant role in our culture because it creates oases of order in an otherwise chaotic world. In architecture this leads to the understanding that every detail should relate to the whole of the building and visa versa. Architecture, then, is about creating material poetry – architectural

pieces where there is an inner logic following its own rules distinct from those of economy and scientifically measurable effects.

Order should here not be understood in terms of the ideals of harmony, symmetry and classic orders. Instead order can be understood as architectural pieces that follow a set of conceptual rules and develops a harmony between elements to adhere to these rules. This way of working can be found in works of deconstruction by Zaha Hadid as well as it can be seen demonstrated in Palladio's Villa Rotunda; see figure 2 and 3. Both pieces of architecture play by rules that remain the same throughout the building and permeate details, construction, plan and facades. This is true even when the only constant in Hadid's fire station is the breaking of the rules – this creates an order of rule-breaking as well as the harmonious world of Palladio does. These oases of order in a chaotic world are fundamental to the way human beings inhabit the world.

While these oases of order could be created through superficial means by applying coherent styles to any given architectural piece, the tectonic writers call for a more profound approach that re-interprets social context, site, materials, building technique and structural principle anew for every architectural project. Since the introduction of a modern concept of space in a modern understanding of architecture, the writings on architecture have tended to focus on the experience created by spatiality (Frampton, 1995). The tectonic view on architecture, however, maintains the prevalence of the material aspects of architecture. In reality, neither the understanding of spatiality nor the materiality can be left out when addressing and creating architecture. From a tectonic point of view, however, the means to create this profound experience should include a concern with materiality, construction and building technology.

Within tectonics there is great diversity between the understandings of the concept. The different approaches are particularly evident when examining the historical writings on tectonics by two of the founding fathers of tectonics as an architectural movement – Bötticher and Semper. Where Bötticher displays a structural understanding of the concept, Semper is concerned with the material aspect of it.

Carl Bötticher – tectonics is a relation between expression and building principles
The tectonic movement in the mid nineteenth century can be understood as a movement against the Enlightenment because it attempts to explain architecture and arts as meaningful even though it does not seem to be so from a rational point of view. The writings of Carl Bötticher (1806-89) should thus be seen as a reaction to Hegels notion of history as a constant development from the primitive's blind struggle for survival, over religion as an intermediate stage to the 'absolute' knowledge of philosophy and science. Hegel understood the appraisal of art and architecture as a kind of religion as well and expected it to vanish in the final phase of the development of society. Viollet-le-Duc defended architecture's continuing importance as a technical, rather than expressive practice (Hale, 2000). Instead of reducing architecture like this, Bötticher attempted to defend architecture from another angle.

Bötticher wrote in the context of an eclectic historicism of the mid nineteenth century where architects had reduced architecture to a matter of choosing between neo-classic and neo-gothic style for aesthetic



Figure 4-5: The difference in style between the Greek temple and the Gothic cathedral masks a similar attitude towards expressing the structural principle

purposes. In this context of historicism, Hegel's understanding of architecture as a kind of religion can even be argued to be true – when architecture is reduced to a choice between styles it becomes a matter of “belief” in a certain style over another.

Bötticher's aim was to move away from this historicism. Therefore he set out to understand the two styles to thereby attempt to find what rendered the styles so different but equally (in his view) great as architectural expressions. What he discovered was revolutionary to the understanding of architecture – Bötticher explained the Greek architecture as an architectural prototype that reflected the structural ability of the lime stone. The short spans and the massive columns and beams suited the lime stone's ability to withstand stress and inability to withstand strain. Equally the Gothic architecture was suitable to the use of wood and stone. With its wide spans, flying buttresses and frail structure it likewise reflected the materials used and the use of another structural principle. The two “styles” of architecture therefore had different expressions as reflections of the different context, the materials used and structural principles applied. Greek and Gothic was thus no longer a matter of two styles but showed how the different principles could be reflected in differing expressions.

On the basis of this examination, Bötticher introduced two concepts to architecture; the concepts of art-form (kunstform) and core-form (kernform) (Bötticher, 1844). The core-form Bötticher defined as his newfound understanding of how the structural principle and the materials used gave rise to a certain architectural expression. The art-form, on the other hand was the visual appearance of the building and what the discussions on styles most often referred to. With his comparison between the Greek and the Gothic styles as originally conceived not only due to an artistic preference but also as the result of the given conditions of the time and place that the architecture was created, Bötticher could criticise the reduction of architecture to the choice between different styles,

"All opinions for or against a particular style have referred only to the outer shell, that is, to the scheme of the building's art-forms, which were considered to be identical with the principle of a style. The true essentials have never been seriously considered; the discussion has never actually turned to the principle and material conditions on which each is based." (Bötticher, 1846, page 150).

Bötticher's examination of the Greek and Gothic architecture made it possible to understand architecture as something more than a superficial choice between styles but as something that had its own inner logic and knowledge base that had resulted in the development of prototypes adequate to each their cultural context, to the materials available and to the structural principle. As such, architecture was not - as Hegel argued - a kind of religion. Instead, Bötticher argued that architects - like the Greeks - should develop a contemporary architectural expression reflecting the given material and technological context.

Bötticher was, with this seemingly rational approach to architecture, not only concerned with structure and construction. He was also very interested in the role of the ornament and was eager to understand why equally the Greek and the Gothic architecture was highly ornamented but in different manners. A closer examination of the ornamentation of the two styles of architecture revealed something interesting. Bötticher found that the art-form - also called the veil (Hülle) because it concealed the structure - were closely connected to the core-form. Actually the art-form continually sought to define the meaning of the core and thus served as something more than superficial decoration. To exemplify the relation between the art-form and the core-form, Bötticher showed how the mechanical function of members of the Greek temple is symbolically represented in the decoration.

"For instance, Bötticher interpreted the Doric cyma, a double-curvature molding that is applied at transitional points in the paradigm of a temple, as a symbol for load and support, a seam within the structure signifying the notions of upright-standing and free-finishing. The curvature of the molding varied, depending on the intensity of the load that was thus symbolically expressed." (Mallgrave, 1996, p. 220).

Bötticher thus discovered that in Greek architecture there was a close relationship between the art-form (ornament) and core-form (structural principle such as post-and-lintel) to such an extent that the leaves of the ornaments bent more where they were carrying a heavier load - the ornament served the function of explaining the structural principle and the ornament had a purpose. This was in great contrast to the use of ornamentation of Bötticher's contemporaries who often would apply a neo-classical façade decoration to a neo-gothic interior. The relationship between the art-form and core-form, Bötticher felt, was necessary to strive for in modern architecture as well. This was a huge shift to the thinking by the theorists before him that regarded the structure and the decoration as separate concerns in architecture.

While mainly interested in the tectonic edifice Bötticher does give direct advice to the contemporary architects on how to create tectonics in practice. Firstly, Bötticher argued, the social demands of function should determine the horizontal dimensions of a building - the extent of the plan. Secondly, the extent of the plan in turn should set specifications for the vertical supports and for the outline of the roof. The roof then should establish the linkage of plan and structure and the type and material of the roof is determined by

climate, material availability and social needs. Thirdly it is the relationship between the plan, roofing and supports and the resulting enclosing and voids, lights and shadows, articulation of materials and colours that creates the character of the architectural space (Schwarzer, 1993). When all parts (structural as well as decorative) of the building are bound together like this, Bötticher calls the architecture tectonic – and thus rejects the idea of applying a decorative façade to a building with another principle.

The rigidity and rationality of Bötticher's advice on the tectonic practice should not lead to a rejection of his main idea of how the structural principle is used to create an architectural expression. It does, however, stress the importance of understanding the tectonic practice from a more open point of view than directing how the tectonic practice ought to take place.

Gottfried Semper – tectonics is how different materials provide different expressions Where Carl Bötticher linked the structural principle and the architectural expression together, Semper did so with the building materials and the architectural expression. While Gottfried Semper was the most influential writers on architectural tectonics and is often regarded as the father of the concept, his later thinking was very influenced by Bötticher.

Bötticher began his investigation to understand the similarities between the Greek and the Gothic architecture. In contrast to this, Gottfried Semper's quest was broader. He wanted to understand what developed the building styles as a whole, not only considering the high points in architectural history. This led him to anthropologic studies where he examined the building culture of primitive cultures in order to understand what led to various styles.

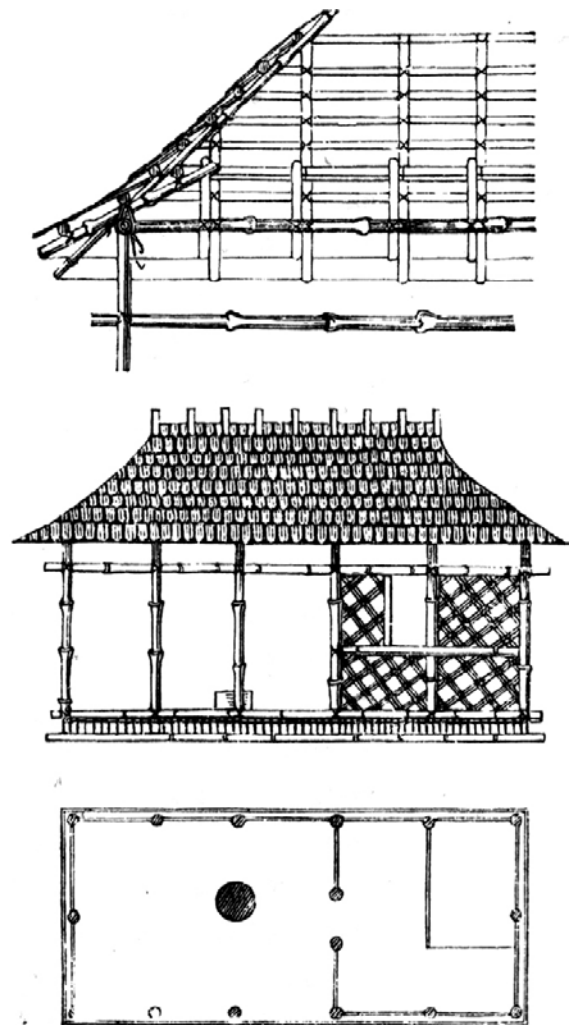


Figure 6: Gottfried Semper was inspired by the Carribian Hut that with its light frame construction contrasted the heavy stone or brick building that surrounded him in Europe

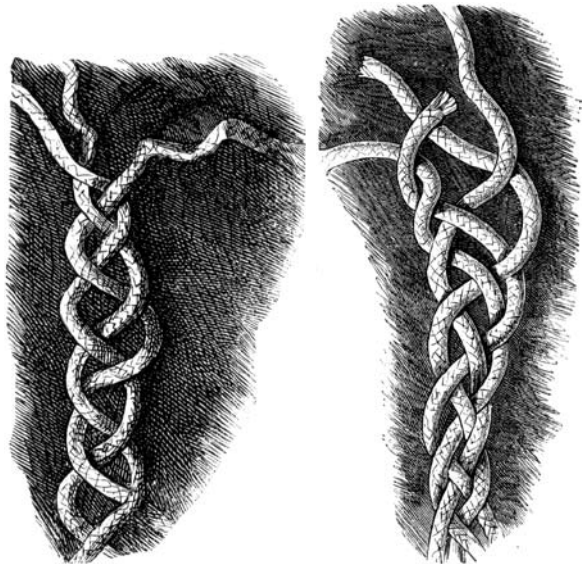
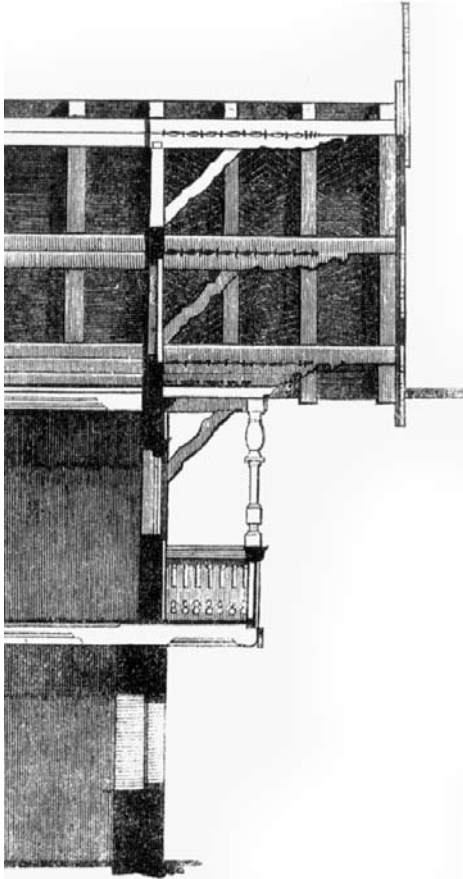
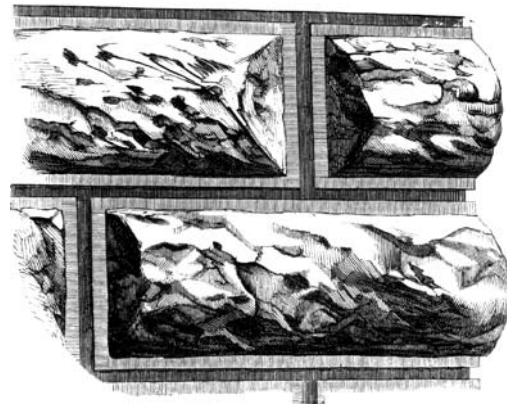


Figure 7-10: Gottfried Semper understood architecture as consisting of four elements connected to the four primary artisan traditions. Ceramics was used for the hearth, masonry was used for heavy stereotomic bases and loadbearing walls, carpentry was used for roofs and the tectonic frame, textiles were used for the enclosure and lightweight room dividers.

The anthropologic studies were the basis of Semper's theory of the four elements of architecture that he developed in his most well-known book *The Four Elements of Architecture* from 1850. His studies of primitive architecture helped Semper to understand architecture as composed of four elements – the surface, the roof, the hearth and the mound. Regardless of the cultural and historical context, this model of understanding architecture could be used to approach the built architecture.

Where Bötticher coupled the material understanding with an understanding of the structural principle, Semper focused more on the craft that was used to shape the materials. As such, Semper developed his idea of the four elements by coupling them to an understanding of how they relied on crafts. He argued how the four elements hearth, roof, enclosure and mound derived from each their material; the hearth would be made from earth or clay, the roof element from wood, the textile element from fibres and hairs, and the mound from stone. The techniques that were used in building and thereby influenced the architectural expression relied on the artisan techniques in the four fields: ceramics, carpentry (tectonics), weaving and masonry (stereotomy). Semper's important contribution to the field of tectonics was to show how the expressions of these materials were conditioned by materials and technique – for instance weaving of threads naturally creates another expression than the carving in wood. In the beginning Semper understood ornamentation and the architectural expression as a whole as a by-product of the technique with which one treated the materials.

Semper developed his idea of the four elements further. A roof should, in Semper's terminology, not be understood only as a roof but as an element that was made as a frame constructed by a number of rigid, (wooden) components. The elements are easily understood from the Carribean hut (see figure 6). Here not only the roof but also the walls of the hut are constructed from wooden elements (the roof element). The hearth is seen as the round figure in the plan and the mound is reduced to a minimum and only remains as stones carrying the wooden columns – instead of being a wall motive, the walls are made from woven textile surfaces.

To Semper the four elements were not equally important. The two most important elements were the hearth – the moral element of architecture – and the enclosure of the woven textiles. The load-carrying structure and the mound were on the contrary only secondary elements that served to support the primary elements of the architecture. In this he distinguished himself from Bötticher's structural understanding of tectonics.

"The first sign of human settlement and rest after the hunt, the battle, and wandering in the desert is today, as when the first men lost paradise, the setting up of the fireplace and the lighting of the reviving, warming, and food-preparing flame. Around the hearth the first groups assembled; around it the first alliances formed; around it the first rude religious concepts were put into the customs of a cult. Throughout all phases of society the hearth formed that sacred focus around which the whole took order and shape. It is the first and most important, the moral element of architecture. Around it were grouped the three other elements: the roof, the enclosure, and the mound, the protecting negations or defenders of the hearth's flame against the three hostile elements of nature." (Semper, 1851, p. 102)

Thereby Semper reduced the columns – which most of his contemporaries focused on – to be a supportive structure only and elevated the textiles to be the beginning of architecture,

“...the beginning of building coincides with the beginning of textiles. The wall is that architectural element that formally represents and makes visible the enclosed space as such, absolutely, as it were, without reference to secondary concepts. ...The structure that served to support, to secure, to carry this spatial enclosure was a requirement that had nothing directly to do with space and the division of space. It was foreign to primitive architectural thinking and was in the beginning not a form-determining element.” (Semper, 1860, p. 254).

Bötticher came to be a major inspiration to Semper's thinking (Mallgrave, 1996). Through Bötticher's analysis of the ornament, Semper became more interested in the symbolic aspect of form. Where Semper initially understood the architectural expression as the sum of the social, material and technical aspects, he (with the inspiration from Bötticher) reluctantly had to acknowledge that the ornament played a much greater role than he first had assumed. In Semper's later writings he acknowledged that the ornament could not only be reduced to a by-product of technique and materials and thereby introduced a distinction between the symbolic and technical aspects of architectural form that reminded very much about Bötticher's distinction between art-form and core-form. Still his focus was, however, on materials rather than structure.

With the inspiration from Bötticher, Semper shifted “from a quasi-materialistic to a symbolic reading of artistic forms” (Mallgrave, 1996, p. 222). He developed his understanding of decoration even further in his most extensive work *Style in the Technical and Tectonic Arts and Practical Aesthetics* from 1860. Here the ornament is seen as a way of applying order to the architectural object and thereby creating an ordered micro-cosmos. He maintained the four elements of architecture and their connection to the artisan tradition but was now able to include the human will to decorate in the understanding of the architectural expressions. As such the new techniques of the industrial production created new possibilities for decorations but could not be seen as the only influence to the expression just as the use of the axe could not in itself explain the expression of primitive huts. Semper thus came to believe that the primary reason to create an artisan tradition and by extension an architectural expression was the symbolic creation of order and meaning in a chaotic world. The need for a secure enclosure sheltered from the climate was the pragmatic reason to build but architecture could, in Semper's view, not be understood without including both the technical and symbolic aspects of building.

Semper refrained from setting any guide lines as to how tectonics should be practiced. Even though he in the beginning of his career was critical of using decorative expressions in materials they were not derived from (Semper, 1852), he later made this change of material a central part of his *stoffwechsel* theory.

Where Bötticher's thinking began as a reaction against an overly abstract aesthetic approach to architecture as a choice between styles, Semper's began as a reaction against the rational focus on the structure as the determining factor in the architectural expression. From each their corner of the field, they reached

the same conclusion; that the architectural expression is conditioned (but not determined) by outer factors. The factors are in Semper's thinking the materials and the component while in Bötticher's thinking it is the structural principle. What is specific to tectonic architecture is not only that the symbolic aspect of construction is understood as the most significant – it is also that the symbolic aspects represent the technical aspects of the architectural piece. Architecture is thus a closed system that refers to itself through a connection between the symbolic and technical aspects.

The primary difference between Semper and Bötticher, that still represents a span in tectonic thinking, is that where Bötticher focused on the structural principles as the basis of different architectural prototypes, Semper focused on the technique to shape materials as well as the relation between the four elements of architecture.

Modernism – structure is the truth hidden beneath the architectural expression

Semper and Bötticher describe the span of the tectonic tradition from a very close focus on the material and technique to a more abstract understanding of a building principle. Both Semper and Bötticher focused on the symbolic as well as the technical aspects of architecture and the reading of their texts served as inspiration to the fathers of the Modernist movement.

It is for instance possible to trace Semper's emphasis on the enclosing surfaces in Adolf Loos' preference for marble and other expensive surfaces as the starting point of his architecture. Likewise Semper's understanding of architecture is echoed in Le Corbusier's understanding of the fundamental difference between construction and architecture as art. While the Modernism is often understood as an "avant-garde" break with tradition the tectonic interest by Bötticher and Semper must, as it was described in the introduction, be seen as a necessary precondition of the Modernism as Kenneth Frampton has described in his "Modern Architecture: A critical History" from 1980.

The interpretation of the tectonics tradition moved during the Modernism, however, far from the intentions of Semper and Bötticher. Soon the understanding of Semper came to be limited to how the architectural expression was directly determined by the materials used and ignored his understanding of culture and society as the starting point. Likewise Bötticher's distinction between the art-form and core-form led to an understanding of that the right way to create "true" architecture was to unveil the core-form to be free of the concealing art-form. The late Modernism thereby signified a dismissal of the relevance of an aesthetic discourse to architecture and a reduction of architecture to adhere to values such as efficiency, rationality and economy.

This reduced understanding of architecture was highly criticised in the Post-modern era. First the discussions were internal in the sense that Modernism was criticised for not having achieved its own goals –for instance by Reyner Banham, who criticises the Modernists for not producing a true machine age architecture (Banham, 1960). Secondly architects and writers began discussing the goals of Modernism and to look for inspiration for a new paradigm in other historical eras and fields. New ideas developed from the criticism of the sterile and context-less Modernism and the notions of context, the importance of a contin-

uing notion of culture through history and the importance of meaning in architecture, arose (Nesbitt, 1996).

In the reintroduction of tectonics during the post-modernism, two schools of thoughts can be found – Kenneth Frampton’s reintroduction of the concept was paralleled by Marco Frascari’s investigations in it. Anne Beim’s writings can be seen as a continuation and development of Marco Frascari’s notion of the concept. Therefore the investigation of tectonics in a contemporary context is carried out through the writings of Frampton (1995) and Beim (using primarily the 2004 edition of her publication but referring to the 1999 edition for clarification of some aspects).

Figure 11: Urban space by Charles Moore



Frampton - reintroducing the symbolism of structure

“The tectonic emphasis is an important part of the postmodern critique of a sterile, debased modernism and of superficial postmodern historicism. Some architects construct a narrative through material and detail.” (Nesbitt, 1996, p. 46).

The post-modern attitude to architecture presented much the same situation as the nineteenth century. The newfound historicism was practiced in an eclectic manner that did not reinterpret its sources but copied elements uncritically as façade decorations that did not have any connection to the core-form.

In the book “Studies in Tectonic Culture - The Poetics of Construction in Nineteenth and Twentieth Century Architecture” Kenneth Frampton sets out to find the remains of our architectural culture, which he in one term calls tectonic.

“For all its marginality, tectonic culture still possesses a vestigially resistant core, particularly

as this is manifest in its proclivity for the tactile." (Frampton, 1995, p. 377).

Frampton describes his own theoretical outset as Semper's writings, but also Bötticher's concepts can be found in Frampton's thinking. As such, Frampton works with two concepts – ontology and representation – that resonates Bötticher's core-form and art-form as well as Semper's symbolic and technical aspects of construction,

"The concept of layered transitional space as it appears in traditional Japanese architecture may be related indirectly to the distinction that Semper draws between the symbolic and technical aspects of construction, a distinction that I have attempted to relate to the representational and ontological aspect of tectonic form: the difference, that is, between the skin that re-presents the composite character of the construction and the core of the building that is simultaneously both its fundamental structure and its substance. This difference finds a more articulated reflection in the distinction that Semper draws between the ontological nature of the earthwork, frame, and roof and the more representational, symbolic nature of the hearth and the infill wall. In my view, this dichotomy must be constantly rearticulated in the creation of architectural form, since each building type, technique, topography, and temporal circumstance brings about a different cultural condition." (Frampton, 1995, p. 16).

Frampton thereby links the concepts of ontology and representation to Semper's elements of architecture pointing to how Semper understood the elements of the hearth and the enclosure as the symbolic aspect of architecture. The enclosure, Frampton argues, in the form of the light infill wall is in its essence representative in the sense that it represents the nature of the construction. This element's function is to articulate and enhance the understanding of the construction.

In opposition to the representation, the ontology of the architecture is both structure and substance in one and does not point to anything else than itself. This concept is linked to Semper's elements of the earthwork and the framework – the stereotomic and tectonic – where the stereotomic is the heavy mass created by piling up material and tectonic is the structural framework created by the assemblage of light linear structural components that is embraced to form a spatial matrix. The opposition between the heavy and lightweight construction holds a poetic dimension,

"It is characteristic for our secular age that we should overlook the cosmic associations evoked by these dialogically opposed modes of construction; that is to say the affinity of the frame for the immateriality of sky and the propensity of mass form not only to gravitate toward the earth but also to dissolve in its substance." (Frampton, 1995, p. 7).

To Frampton a focus on the bodily experience in the creation in of architecture is the key to lifting building from rational construction to architecture with a cultural significance. Tectonics, to Frampton, is therefore "the poetics of construction" - as is the subtitle of his publication – where poetics should be understood in its Greek sense; as art. This poetics of construction is achieved by the constant re-articulation of the relationship between the two concepts of representation and ontology with regards to the specific topography,



Figure 12-13: Frampton distinguishes between the sculptural approaches of Gehry and Miralles. Miralles' approach encompasses a concern with tectonics while Gehry's does not.

technique and conditions of each building. This articulation is what leads to a varied cultural expression varying from the Chinese temples with paper to the heavy masonry temples of the Mayan Indians. By using local materials and developing local crafts traditions, Frampton argues that a varied local and contemporary architecture can be developed. An example of such a local and contemporary architecture is for instance Sverre Fehn's architecture.

In this respect, Frampton is not only continuing the tectonic tradition from Bötticher and Semper, he is also developing it. Where Semper set out to understand why architecture looks different in various contexts as an explanatory exercise, Frampton reverses the argument and argues that architecture should look different in the various contexts. In Frampton's hands, tectonics becomes an argument against the Internationalism of the modern movement, the tabula rasa approach and the post-modern use of disconnected historical references – in all it became an argument for the Critical Regionalism.

Frampton thus unfolds the critical potential of tectonics and argues that the humane balance between the ontological and representational aspects of architecture is endangered in a world of imagery. This is due to the many factors such as the building industry which increasingly distances the architect from the tech-

niques of construction, the architectural education where the image has come to be more significant than the substance and European politics that only measure architecture in terms of economy and market forces (Frampton, 1995). This has created a situation in which the primary opposition towards the tectonic culture is an exaggerated focus on the aesthetics. As an example of this, Frampton points to Frank Gehry's work,

"...where does structural expressivity lie between sculpture on the one hand and architecture on the other? How can one demonstrate this difference by example, or, more precisely, how can one demonstrate the limits of the sculptural versus the tectonic within architecture? For me this is a point at which one may discriminate between Frank Gehry and Enric Miralles, say. In almost all of Miralles's work the tectonic element is closely integrated with the sculptural. In Gehry's case, apart from his very early work, there's no interest whatsoever in the tectonic. He's only interested in plasticity, and whatever makes it stand up will do—he couldn't care less. That's very evident in Bilbao." (Allan and Foster, 2003).

The continuing creation of tectonics is demonstrated by Frampton through the architectural edifices created by a number of architects such as Frank Lloyd Wright, Scarpa, Kahn and Jørn Utzon. As argued in the introduction, however, Frampton's demonstration of contemporary tectonics does primarily focus on the architectural edifice rather than the practice.

ONE TRUE TECTONIC APPROACH?

The writings of Bötticher, Semper and Frampton are close in their understanding of what tectonic architecture is and the aim of it as oases of order. They differ, however, in their understanding of how to achieve this in architecture. Where Bötticher points to a representation of the structural system, Semper places emphasis on the material and techniques for processing materials and Frampton refrains from pointing to one approach but points to the common denominator of the corporeal experience. Since the aim of this thesis is the tectonic practice; it is crucial to come closer to an understanding of how tectonics is practiced and an attempt to line up various approaches is illustrated in the list below. Note that they all fall under the initial understanding of tectonics as ways of creating a human experience through the materiality of architecture:

- To intentionally use existing building materials to achieve a certain human experience (Semper/Frampton)
- To respond to new building materials with new architectural expressions (Semper/Frampton)
- To develop new building materials to create certain human experiences
- To intentionally use techniques in material processing to achieve a certain architectural expression (Semper/Frampton)
- To respond to new techniques in material processing with new architectural expressions (Semper/Frampton)
- To develop new techniques in material processing to achieve a certain architectural expression (Semper/Frampton)

Frampton)

- To intentionally assemble building components to achieve a certain human experience (Semper/Bötticher/Frampton)
- To respond to new building components with new architectural expressions (Semper/Bötticher/Frampton)
- To develop new building components to create certain human experiences (Semper/Bötticher/Frampton)
- To intentionally use structural principles to create architectural expression (Bötticher/Frampton)
- To respond to new structural principles with new architectural expression (Bötticher/Frampton)
- To develop new structural principles to create certain human experiences (Bötticher/Frampton)

The list – like the discussion of Semper's and Bötticher's writings - reflects that a tectonic approach can vary from a sole concern with materials and techniques (the first six approaches), over the concern with the demands to building elements (the next three approaches), to more principal concerns such as structural principles (the last three). In each of these approaches the aim is a fruitful connection between ontology and representation but the beginning point to achieve this varies.

One of the writers, who have coupled the understanding of tectonics with an analysis on how to achieve tectonic architecture with industrial building technology, is Anne Beim. In the publication "Tectonic visions in architecture" (2004) Beim divides the tectonic practice into three themes called "Process and Technology" - representing the shaping of materials in an industrial building process, "Component and Composition" - representing the influence of an industrial production and how to achieve a meaningful architectural expression with the use of pre-fabricated building elements and "Separation and Integration" dealing with the architectural principles and the building morphologies.

Her three concepts group the approaches identified in a meaningful way and in the following the understanding of tectonics will therefore be grouped in three main approaches. The first group is called Materiality and Technique and consists of the first six approaches where it is the material and technique that is the focus of the tectonic approach. It is close to Semper's understanding of how the building materials used as well as the technique used to shape the materials will influence the architectural expression. One example of this approach is Louis Kahn's use of a bricks to create a tactile surface that portrays the structural forces running in the façade as well as it uses the material in a way that develops the architectural expression that is inherent to the expression. Louis Kahn is a master when it comes to working tectonically with a material. In great contrast to his way of working with the brick are the many contemporary brick facings where the relieving arches have been abandoned and the heavy material is being carried rather than being load-carrying. To maintain a traditional façade, then, the material is in those cases being used as brick-wallpaper rather than working consciously with the strengths and limitations of the actual material.

The next group is called Component and Composition (borrowing the term directly from Beim) and covers the three next approaches of the list. The focus is here on how building elements can be chosen and assembled to achieve various architectural expressions – much like Semper's understanding of how the




| Materiality and Technique | Component and Composition | Building Principles |
|---|--|---|
|  <p>Use of existing material and technique (Library, Louis Kahn)</p> |  <p>Development of new building components (Sydney Opera House, Utzon)</p> |  <p>Ventilation need giving rise to building organisation (Medical building, Louis Kahn)</p> |

Figure 14: Tectonics can be understood as three tectonic approaches.

four architectural elements can be used to create various architectural expression by varying between a light tectonic architecture and a heavy stereotomic architecture. In Beim's writings the aspect of component and composition has taken on an additional dimension than Semper's understanding because it is used in connection to the industrialisation of the building process, where the production of building components is divided from the architectural profession. Unlike Semper's, Beim uses the term to address the creation of tectonics by the assemblage of industrialised elements. One example of this tectonic approach is Jørn Utzon's building system developed for the Sydney Opera House. Due to difficulties with obtaining a good result with in-situ casting as well as the issue of how to subsequently clad the sails with tiles, Utzon decided to take advantage of an industrialised production of building components with a reliable quality that could be assembled quickly. With this system Utzon demonstrated how the industrial production of building components does not necessarily rule out curves in the architectural form.

The last group is called Building Principles and refers to the last three approaches that are concerned with the development of building principles. Bötticher places great emphasis on this group when he argues that the Greek and the Gothic architecture is fundamentally different because they are based on different structural principles and therefore should also appear different to represent their ontology. Where Bötticher understands principles as structural principles, Beim broadens the understanding to include other principles (ventilation and climatic concerns) that serves as structuring or formative to the architectural idea. This is the notion of principles that is also used in this thesis where acoustics is seen as the basis of the formative principle. In the Building Principles, it is the inner organisation, the ontology of the building that is the starting point of the architectural expression. One example of this approach is Louis Kahn's use of ventilation as a Building Principle where he developed the architectural scheme for the medical building to solve

the requirements of fresh air to the studies and removing air from the laboratories. One example where the Building Principle is not used as a generator for the architectural form is Frank Gehry's Guggenheim Museum, where the impact of the structure to the architectural expression is limited to a gap between the outer and inner facades wherein the structural engineers could distribute adequate amounts of metal.

The division into differing approaches is useful because it opens up the concept of tectonics to encompass a wide range of approaches varying from using known materials, components and principles to approaches that in themselves develop new technologies.

The identification of these equally valid tectonic approaches serves as a rejection of the thought of one true tectonic approach. All three approaches fall under the understanding of tectonics.

THE RENEWING POTENTIAL OF TECTONICS

One of the most interesting aspects of Anne Beim's writings is her definition of the relationship between technology and architectural approach. Her analysis clearly demonstrates the renewing potential of tectonics. This renewing potential was evident already in connection with Bötticher and Semper; their urge to understand Greek architecture may seem conservative, but their actual aim was to be able to understand architecture beyond stylistic variations, and thereby move forward in a time of eclectic historicism. Beim's understanding of architecture and technology, however, can be used to describe the tectonic practice rather than the tectonic edifice wherefore it is highly relevant to this study.

Also today tectonics holds a potential to renew the architectural expression and the range of prototypical solutions that the practitioners draw upon when developing the architectural schemes into actual realisation. The degree of renewal, however, varies among the tectonic projects. Because it provides a terminology of tectonic approaches, it may be used to argue that a tool is ready-to-hand to create one kind of architecture while inappropriate to create another.

Beim distinguishes between different ways of working with technology in architecture and describes how the starting point for the development of technology can be architectural expressions, as well as architectural expressions can be developed through the use of new technology:

"The architect pursues either a conventional approach, based on prevailing ideas or a visionary approach, based on new/transcending ideas. These two sets of approaches relate either to conventional technologies or new technologies. However, opposite movements may also happen, where different sorts of technologies inspire different approaches and come equally to form a new setting for the architect's original standpoint." (Beim, 2004, p. 20).

This leads to four fundamental directions in the relation between architectural approach and technology (these are described by a diagram the 1999 edition of *Tectonic Visions in Architecture*),







| | Materiality and Technique | Component and Composition | Building Principle |
|---|---|--|---|
| <p>New architectural expression through the use of known technology</p> <p>Trad.tech. ↔ New arch.</p> |  <p>Use of existing material and technique (Library, Louis Kahn)</p> |  <p>Use of existing building components (Bagsværd Church, Utzon)</p> |  <p>Use of known structural principle (Graz art-museum, Peter Zumthor)</p> |
| <p>Development of new architectural prototypes through application of new technology</p> <p>New.tech. ↔ New arch.</p> |  <p>New concrete casting technique enabling new spans in thin concrete shells (TWA terminal, Saarinen)</p> |  <p>Development of new building components (Sydney Opera House, Utzon)</p> |  <p>Ventilation need giving rise to building organisation (Medical building, Louis Kahn)</p> |

Figure 15: Within each of the three approaches the architectural expression can be developed from new or traditional technology

Traditional technology ↔ Traditional architectural approach
Traditional technology ↔ New architectural approach
New technology ↔ Traditional architectural approach
New technology ↔ New architectural approach

In this thesis tectonics is interesting primarily due to its potential for renewal in terms of architectural expression and technology. In the diagram below, architectural examples where new architectural expressions have been developed through the use of traditional or new technology are demonstrated. The approach with traditional architectural ideas has been left out of the diagram for clarity.

A very common relationship between architecture and the use of technology is when an architectural project uses known technological principles to create a new architectural expression. One example is Jørn Utzon's use of building components from storage houses and greenhouses. Even though Utzon used it in a different context (a church), the principle was not new. This approach can give an architectural expression that has never been seen before, but it does not add to the known technological principles.

The relationship between new technologies and new architectural expressions is where the tectonic approach holds the greatest potential to develop the architectural field and the building industry in general. This was for instance the case with the TWA building by Saarinen. This building has an architectural expression and main shape that is clearly conceived with a point of departure in the new concrete casting technique.

The understanding of how the architectural expression is closely linked to Materiality and Technique, Component and Composition, and Building Principle is thus not only something that can be used to explain ancient architecture. On the contrary, it can also be used as a guide when concurring new territories of the architectural future.

In the model below the more or less renewing principles are coupled with the three groups of tectonic approaches. From left to right the three approaches (as mentioned inspired heavily by Beim, 2004) to tectonics are presented. At the top a traditional technology is used to develop an architectural approach, and at the bottom a new technology is used to develop a new architectural approach.

CONCLUSION AND LIMITATION

In this chapter the concept of tectonics was unfolded through the writings of Semper, Bötticher, Frampton and Beim. The writings on the concept of tectonics have a number of common denominators: the rejection of architecture understood as a superficial application of styles as well as the rejection of architecture understood as a merely rational endeavour.

Within this general direction, however, the writings have many differences in their respective approach to

defining tectonics. Semper focuses primarily on understanding how the material used in architecture, the technique to process the material as well as the function of the element influences the architectural expression in various cultures and contexts. Bötticher focuses on how materials and structural principles condition and are conditioned by the architectural expression. Frampton is highly inspired by Semper, and argues for a regional architecture where the use of materials is always reformulated with regards to the topological, social and cultural reality defined by the context. Beim analyses how tectonics can be used as an inspiration (materially as well as metaphysically) and thereby enable architects to address the changing conditions in an industrial age of new materials, industrial building technology and increasingly complex demands to architecture.

The aim of the chapter was to unfold the concept of tectonics rather than attempting to limit the understanding of tectonics. Inspiration to divide the concept of tectonics into three approaches was found in Beim's writings. The review was therefore concluded by outlining three major approaches to tectonics found in the writings – Materiality and Technique, Component and Composition and lastly Building Principle.

The first approach, Materiality and Technique, is concerned with how materials, their function and the technique with which they are processed, influence and condition the architectural expression. The second approach, Component and Composition, is concerned with how building components, their assembly and the joints between them, influence and condition the architectural expression. The third approach, Building Principle, is concerned with how the choice of structural, environmental and acoustical principles in a building influence and condition the architectural expression. The three understandings of tectonics focus on each their aspect of the architectural edifice. Together, they span from the smallest scale of the material to the largest scale of the organisation of the building. A piece of architecture can be tectonic either by being concerned with all three tectonic approaches or by focusing solely on one or two of the approaches. Within each of the three tectonic approaches, it is therefore possible to work in a more or less renewing manner.

The most widespread understanding of the concept of tectonics is found within the first two approaches and in the last approach, Building Principles, most often it is only the structural principles thought of in connection with tectonics. Therefore, non-structural Building Principles are all the more interesting. With the increasing growth of the fields of knowledge related to architecture (fire protection, indoor climate, IT installations, energy consumption, architectural lighting, acoustics etc), the tectonic approach of Building Principles becomes increasingly relevant. Due to the professional specialisation, these fields have developed to be professional fields in their own right with their own field of knowledge, journals and success criteria. This independence is problematic when the architects are attempting to draw upon it in connection with developing tectonic architecture as the knowledge held in the fields does not aim directly at developing architectural form. Tectonics in the Building Principle approach is therefore interesting to understand as it is unfolded in the tectonic practice. In the case studies, the focus will therefore be on tectonics in the Building Principle approach.



Figure 1: NOX water pavilion

THE CONCEPT OF TECTONICS IN THE DIGITAL ERA

From the focus on the concept of tectonics in the pre-digital era in the last chapter, the focus will now shift to the concept of tectonics in the digital era. There are numerous fields of research investigating the computer in the architectural and engineering practice – for instance the field of Design Computing and Cognition led by John Gero who is concerned with how designers think through the computer (Chen, 2001); digital architecture concerned with the new aesthetic language enabled by the computer design (Mitchell, 1999a; Zellner, 1999); Industry Foundation Classes (IFC) concerned with information sharing in the collaboration between the component industry and the architects and engineers (summarised by Plume and Mitchell, 2005). The problem with these approaches is that they do not distinguish which kind of architecture is being created – any building will do. Also the engineering and architectural collaboration is not discussed in connection to the early process. It is therefore difficult to relate to the tectonic practice of architecture.

The only proposal to this connection between the computer and the tectonic so far is found in the writings of digital tectonics and this group of writings are therefore highly relevant to the research. The selection of writings that this study draws on as its fundament to understand tectonics and to critically assess the relation between the computer and the tectonic practice is therefore the writings from the digital tectonics. The aim of this chapter, then, is to discuss the understanding of tectonics in these contemporary writings. Due to this aim, a wider discussion of the theoretical foundation of writings on digital architecture has been left out.

Through the critical assessment of the concept of digital tectonics it is attempted to create leverage to develop a broader understanding of the tectonic practice and its relation to (digital) design tools. In the end of the chapter two competing or complementary models to understand this relationship will therefore be proposed. These models attempt to describe the tectonic practice through the human actor, the collaborating professional fields and the relation of the design tools to these.

From fascination with the computer technology to critical assessment – the background of digital tectonics

“By the end of the nineteenth century, the impact of the industrial revolution was widely felt in architecture and urbanism. ... At the close of our century, it is the information revolution that is metamorphosing architecture and urban design.” (Zellner, 1999, p. 8).

The background of the concept of digital tectonics is the introduction of the personal computer as a design tool in the architectural practice. The information age that began at the end of the twentieth century was directly linked to the ability to process information – an ability that the computer gave rise to (Castells, 1996). The first direct influence to architecture came from drafting programmes that emerged in the 80s. The first tools mimicked the drafting procedures of the hand-drawn architectural blue-print but later the three-dimensionally based design tools were more far-reaching in their ability to produce digital images and served as a tool for the development of architectural ideas (Kolarevic, 2003).

Initially the concern with the digital was understood as an opposition to the concern with the tectonic

quality of architecture. Greg Lynn pointed towards this with his article on why tectonics is square and topology is groovy (1996) and William Mitchell underlined it with his article on the Antitectonics: Poetics of Virtuality (1999). Both writers (as well as a number of practitioners such as Cache, 2002 and Spuybroek, 2003) expressed their impatience with the tectonic understanding of architecture which they understood as reducing architecture to a response to the forces of gravity and resulting in boring, rectilinear architecture. It could be argued that this opposition towards the tectonics was connected to tectonics being addressed as a quality of the architectural edifice rather than a certain practice – if the practitioners do not understand or agree with the architectural edifices characterised as tectonic, they can dismiss the thought of tectonics on the basis of this.

The anti-tectonic view on architecture can be said to epitomized by the Guggenheim Museum in Bilbao by Frank Gehry built in 1997 (Mitchell, 1999a). The mere shape of the building was a token of the digital architecture where curves and free-flowing space were predominant instead of rectilinear shapes. Likewise the design, manufacturing, and construction were digitally driven.

The Guggenheim Museum was, however, also a pivotal point in computer technologies' role in connection to architecture. Frank Gehry was primarily concerned with the spatial and aesthetic qualities of the building and less with traditional tectonic qualities such as expressing the structural principle. While the Guggenheim can be argued to be tectonic in connection to Materiality and Technique due to its interesting use of sheet metal, it lacks tectonic qualities at least in the Building Principle approach. The structural concern was, as such, restricted to leaving a gap between the outer and inner surface wherein the engineers could apply the structure necessary.

While one group of critics (Kolarevic, 2003; Abel, 2004; Szalapaj, 2005) were fascinated by the free-form curves and the new use of materials, another group (Frampton, 1995; Leach, 2004) were critical towards how the architect failed to take advantage of the expressive potential of the structure. As such, Frampton argued that Gehry was creating a sculpture rather than a piece of architecture (Allan and Foster, 2003). Similarly, Leach criticises Gehry's work for being "...excessively formal, scenographic work..." (Leach, 2004, p. 73). Thereby the thinking about computer technology entered a new era; from an initial enthusiasm and experimentation with the new media to the critical assessment of what role the computer technology can play in creating tectonics. Directly or indirectly the Guggenheim thus gave rise to the introduction of the concept of digital tectonics.

Introducing the concept of digital tectonics

The term tectonic was initially used in connection to the digital medium in a transferred sense meaning how bricks were replaced by bits in digital architecture (Novak, 1995) but today the concept "digital tectonics" has wider implications. The concept seems to have been used for the first time by Beesley and Seebohm in 2000. They used the concept to describe a move of the highly abstract designs often produced in digital environments towards a design more closely concerned with physical materials and construction. Beesley and Seebohm defines digital tectonics as "an evolving methodology that integrates use of design software with traditional construction systems" (Beesley and Seebohm, 2000).

This juxtaposing of the tectonic and the digital resonates a general maturing of architecture conceived digitally. This maturing was driven by an increasing part of digital architecture actually being built and thereby facing new challenges connected to transforming the digitally conceived designs into construction information. The digitally conceived designs often had complex shapes and were so difficult to represent in the traditional plan, section and elevation that a digitally fabrication and construction evolved;

"...out of sheer necessity, the designers of the digitally-generated "blobby" architecture became closely involved in the digital making of buildings."
(Kolarevic, 2003, p. 57).

This renewed interest in the material aspects of building added a new dimension to the digital architecture. This was the background for the concept of tectonics being re-introduced even though tectonics in this connection was understood in its everyday meaning as the inevitable in building and was far from the exclusive and rich concept of Semper, Bötticher, Frampton and Beim.

The concept of digital tectonics in a broader sense was first cemented in 2002 by a symposium at Bath University supported by the engineering firm Buro Happold. Led by Neil Leach, theorists as well as practicing architects and engineers were asked to contribute to the emerging paradigm through writings and discussions.

Following the spark of interest ignited by the symposium, a number of writers became concerned with the new concept. Both Jeremy Ham (2003) and Wassim Jabi (2004) are concerned with to what extent the computer can be used as a pedagogic tool for teaching architectural students about structure and construction. They use the concept of



Figure 2, 3 and 4: The structure of Guggenheim in Bilbao under and after construction demonstrates how the Building Principle has no connection to the architectural expression but is effectively covered – even concealed – during construction.

digital tectonics to describe the move from the purely digital to a more material concern in conjunction to the digital design. Beesley and Seeböhm as well as Ham and Jabí can be said to be primarily interested in outlining the practical consequences of what they see as a new potential for the digital medium to link to the physical world.

The publication *Digital Tectonics* (2004) summarised the discussion at the symposium at Bath University. It consists of the contributions to the symposium edited by Neil Leach, David Turnbull and Chris Williams and was laid out to “provide a manifesto for a new culture of digital tectonics” (Leach, Turnbull, Williams, 2004, p. 5). This publication links the digital tectonics to an emerging structural turn in architectural thinking as well as a new potential of the digital to support this character of the architecture.

Following the publication of the ‘manifest’ for digital tectonics, another direction in the writings was begun by Wan-Ping Gao in 2004 and continued by Yu-Tung Liu and Chor-Kheng Lim (Gao, 2004; Liu and Lim, 2005a, 2005b). Gao asks, “Could the use of computers as a medium in design be considered a new type of tectonics?” (Gao, 2004, p. 3) and ends up concluding that the traditional concept of tectonics cannot cover the digital architecture and therefore needs to be ‘updated’. Gao, Liu and Lim’s understanding of digital tectonics attempts to inscribe all digitally generated architecture into the tectonic realm. In their writings they are as such indifferent to whether the intentions behind the architectural projects have been tectonic or not. When understanding tectonics as an exclusive term – as it was argued in the introduction – this inclusion of all digital architecture is ambiguous. Secondly, the attempt to adjust the concept of tectonics to the digital architecture disregards the versatility of the original concept and neglects the strength of the concept by arguing that it needs to be renewed. It seems that if the concept was strong enough to apply to the master builder era as well as the industrial era, it can apply to the current era as well without changing the core of the concept. In the following, Gao, Liu and Lim’s direction in understanding digital tectonics is therefore not followed.

Digital tectonics is a relatively new concept and it is far from being as intensively studied theoretically as the original concept of tectonics. The juxtaposition of two seemingly contradictory terms – digital and tectonics – should in many respects be understood as a provocation and a catchphrase rather than a serious theoretical investigation. Nevertheless, the writings under the heading of digital tectonics explore the relationship between the digital and the tectonic and are therefore important and relevant to this research. Among the relatively sparse number of writings on the subject, the most relevant source to an understanding of digital tectonics is seen to be the publication *Digital Tectonics* by Leach, Turnbull and Williams. In the following, the understanding of digital tectonics will lean on this publication and whenever digital tectonics is mentioned, it is implicit that it is the understanding of this concept as presented by Leach, Turnbull and Williams that is meant as well as *Digital Tectonics* (with capitals) refers to their publication of this name.

Digital Tectonics – focusing on practice instead of built edifice

The most significant writings from the publication *Digital Tectonics* (Leach et al, 2004) are provided by Manuel DeLanda and Neil Leach himself while the projects from Greg Lynn, Kristina Shea and Bernard Cache are the most explanatory architectural examples.

Leach defines his understanding of digital tectonics by arguing that it is as if the whole history of architecture can be divided into two fundamentally different ways of understanding form – an understanding that he bases on Deleuze and Guattari. On one hand there is the Classical (Renaissance, Mannerism, Baroque, neo-classical) understanding of architecture where form is created by imposing stylistic preferences as sets of rules. On the other hand there is the Gothic understanding of architecture where form is constantly negotiated and influenced by materials and programme. The Gothic approach is then more of a method than a style and more focused on structure than the Classic,

“Architecture becomes the result of competing forces. It is a programmatic architecture that registers the impulses of human habitation, and adapts to these impulses.” (Leach, 2004, p. 73).

The distinction between the Classic and the Gothic is by Leach paralleled by the distinction between a static and a dynamic model of understanding architecture. Leach argues that the general tendency in science and society at large is a rejection of the static in favour of the dynamic. In architecture the static, Classic approach to architecture is “...any outlook which focuses on appearance over performance.” (Leach, 2004, p. 73) and exemplifies it with Modernism, Post-modernism as well as in the work of Frank Gehry.

The dynamic, Gothic understanding of architectural form gives, to Leach, rise to a renewed interest in tectonics because it signifies creating architectural form as a result of materials, construction and structure rather than a purely stylistic approach. Leach argues that this dynamic approach is re-emerging and identifies the Gothic or tectonic spirit in the work of architects such as Reiser and Umemoto, UN studios, FOA, Mark Goulthorpe and Lars Spuytenbroek because of their “sympathetic engagement with the principles of structural engineering” (Leach, 2004, p. 74). In Leach’s enthusiasm for the structural principle and rejection of styles, he resonates Bötticher’s understanding of tectonics.

Leach’s understanding of architectural styles being concerned with appearance and others with performance can be questioned by arguing that the oppositions are interdependent – that any architectural movement begins with new ideas and ideals about performance (the Modernism certainly did) but can end up being copied endlessly as a style with no concern for the original ideal. Also it would be difficult to identify any architectural project that was not concerned with performance in some respect – one example of this is Frank Gehry’s Guggenheim Museum. Leach uses this as an example of the Classic approach but as it has already been argued, the design is concerned with performing in connection to materiality and component even though not in connection to structural engineering. This reveals that Neil Leach is primarily interested in tectonics within the Building Principle approach.

Also - despite this black and white division between the Classic and Gothic understandings of architecture – Leach’s distinction can be used to ascertain that he is interested in tectonics as a practice rather than edifices. The distinction between architecture concerned with appearance and architecture concerned with performance can be compared to the distinction between concerns with tectonics as an edifice as opposed to tectonics as a practice. The Classic understanding of architecture (like the authors addressing tectonics

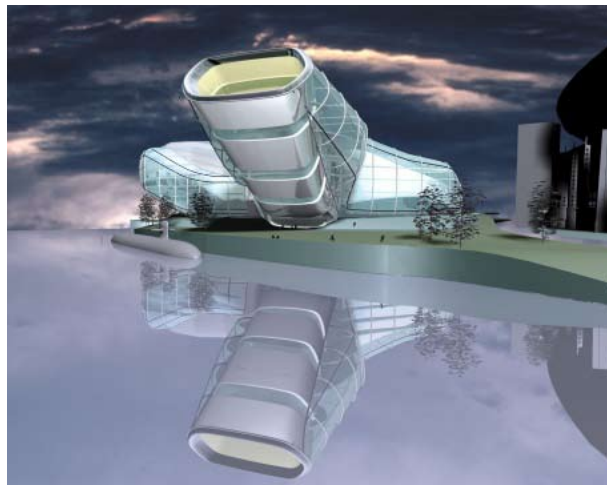


Figure 5, 6 and 7: Highrises in Dubai by Reiser and Umemoto, Yokohama Port terminal by FOA, and Carnegie Science Centre by UN studio

as an edifice) discusses how architecture should appear while the Gothic understanding of architecture (like addressing tectonics as a practice) discusses how architecture is created. Leach's writings on digital tectonics can therefore be understood as a contribution to the debate on tectonics as a practice.

Touching all three tectonic approaches

The references between the writings of the digital tectonics and the historical and traditional groups of writings are very limited. In fact, the only direct reference that Leach makes is by arguing that Frampton's book on tectonics can be seen as one long argument against the digital (Leach et al, 2004). Nevertheless, the understanding of tectonics that is presented in Digital Tectonics still addresses the same three tectonic approaches identified in the original understanding of tectonics.

While Leach primarily focuses on tectonics in the approach that is here addressed as Building Principle, he does touch upon how the computer can affect the Component and Composition and exemplifies this with

the work of Bernard Cache who concentrates on rendering the transformation of a digital design into digital manufacturing information smoother. This implies, for instance, writing software that enables an automated detailing of architecture.

The last tectonic approach, Material and Technique, is also addressed in the publication. Manuel DeLanda (2004) argues that a reduced understanding of the complex behaviour of materials has led to architecture that is unable to reflect the complexity of a structure – this is for instance seen in the use of refined steel as a building material regardless of the structural necessity of a given structural member. The use of computers for calculations can enable a more complex understanding of building materials and thereby result in an architecture where each structural member reflects its actual structural function. This development of architectural elements from their material complexity is quite close to Semper's understanding of the development of form.

What is evident from the writings in Digital Tectonics is that like the original concept of tectonics, digital tectonics is not one uniting approach but rather a theoretical umbrella spanning a collection of approaches.

CAN THE BUILDING PRINCIPLE APPROACH BE SUPPORTED BY THE COMPUTER TOOLS?

To Leach (as well as to the present research project) it is primarily the Building Principle that is of interest. Where the computer has primarily been used in connection to presenting completed architectural schemes through the ability to visualise (Chaszar, 2006), digital tectonics is concerned with how the computer can increasingly be used to generate architectural schemes through structural concerns.

Leach finds that one of the most interesting and promising examples of this is Kristina Shea's work with eiffForm because the computer becomes a "co-designer" that can generate novel structural forms from a given set of parameters; "The computer provides an efficient search-engine that is premised on the notion of efficiency" (Leach, 2004, p. 75). The perspectives of this work are, according to Leach, that similar programmes could inform other areas such as environmental concerns or acoustics and thereby contribute to the formation of form in a Gothic sense. Another example of the computer in this tectonic approach is Buro Happold's generation of the exact geometry of the roof structure over the British Museum in London. In that context the programme for analysing the structure was written specifically for the project by Mike Cook (Cook, 2004).

The main point proposed by Neil Leach is worth noticing: the understanding that a tectonic practice is a close collaboration between structural (or acoustic, climatic etc) and other architectural concerns in the beginning of the design process, thereby supporting the development of an architectural concept that "...embraces structural concerns not as some practical afterthought, but as a vital component folded into the whole conceptual process of designing" (Leach, 2004, p. 74). It is, as such, clear that the aim with introducing the tectonic aspect into the digital is to create a distance to previous writings discussing the computer in architecture only from an aesthetic perspective.


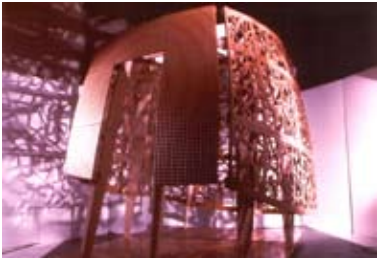

| Materiality and Technique | Component and Composition | Building Principles |
|---|---|--|
|  |  |  |
| Gregg Lynn experimentations with ornaments | Bernard Cache production of building components from projective geometry design | Kristina Shea computer generation of structural solutions |

Figure 8: Neil Leach's understanding of digital tectonics touches upon all three tectonic approaches found in the historical and traditional writings

There are, however, also aspects of Neil Leach understanding of digital tectonics that is questionable from the previously presented understanding of the tectonic practice and the historical understanding of the concept of tectonics.

The lone practitioner

The presentation of the use of digital design tools in the publication *Digital Tectonics* represents a clear-cut image of the individual actor being able to work with the structural field much easier and fluently thanks to the digital tools. The eifForm programme is presented as working as a co-designer with the architect by generating structural solutions to architectural schemes. The British Museum example is presented as an example where the calculating powers of the computer allow the engineer to optimise an architectural scheme geometrically with respect to structural considerations. In both cases, then, the use of computer programmes is presented as enabling a lone practitioner to work with the structural field. In addition, the manifest attempts to brush over the professional differences by arguing for the emergence of a new hybrid practitioner, "...we are seeing the emergence of a new hybrid practitioner – a kind of architect-engineer of the digital age." (Leach et al, 2004, p. 4-5).

However, it is still clear that the eifForm programme is directed towards architects, and the optimisation in the British Museum is created and used by engineering programmers. The hybrid practitioner might be emerging, but the professional boundaries are still very present in the computer programmes described in the *Digital Tectonics* manifest. The fundamental challenge to the practice of tectonics in the Building Principle approach is therefore still present: the engineers possess the technical knowledge that the architects need to incorporate into the design as Building Principles.

The proclamation of a manifest is expected to be very modern and innovative but is the presentation of the computer programmes as enabling a single practitioner not actually a revival of the dream of the master builder where the architects are free of their dependency on engineering consultants?

In the professional reality it is a rare occurrence that the tectonic quality is created by one actor using a design tool, and in order to seriously discuss the degree to which digital tools can enable a tectonic practice, this contemporary complexity of the architectural practice must be taken into account. The question remains, then, to what extent the tectonic practice in a collaborative situation is enabled by the computer as a design tool.

Understanding of tectonics

The relation between engineering and architecture that Digital Tectonics describes inherently defines the understanding of tectonics that is being advocated. Even though the writings on digital tectonics deal with the concept in the same three approaches as the historical and traditional writings do, there is reason to be hesitant in declaring Leach's understanding of tectonics identical to the pre-digital understanding of tectonics. Jean Pierre Chupin (2005) has discussed how digital tectonics is closely related to digital architecture, which is significantly different from the concerns within tectonics. Chupin notes,

"... we should pause over the assumption that the tension between digital culture and tectonic culture has collapsed or has already been resolved, made without considering the respective relationships of these concepts to "space" and to the fall of the body..." (Chupin, 2005, p. 69).

Traditionally, the digital tradition has focused on spatiality and less on materiality. The fluid spaces with double curvatures are often a signature of digital architecture that is reminiscent of the weightless digital space in which it is perceived in. The work of NOX, which is one example put forward in the Digital Tectonics publication, demonstrates this tendency. The tectonic tradition, on the contrary, is characterised precisely through its concern with materiality as well as spatiality. This indicates that the opposition between digital architecture and the tectonic tradition is to some degree still present in the concept of Digital Tectonics.

By using Beim's relations between technology and architectural approach, it seems clear that a generative programme such as eiffForm can structurally develop a new architectural expression by applying a traditional structural solution. Neil Leach (2004) sees this programme and similar ones in acoustics and environmental concerns as the future of digital tectonics. This tectonic future would, however, be based on an understanding of tectonics as the realisation of new architectural expressions, rather than a mutual relationship between the technological and architectural approach. In this context, digital tectonics is still perceived as being in the service of solving an architectural expression, rather than the architectural expression being developed from the technological substance of the project.

Understanding the practice of tectonics in the digital era

The computer tools may be able to support the tectonic future, but when Leach et al attempt to argue for the computer's ability in connection with tectonics, they ignore at least three aspects:

- Tectonics as a mutual relationship between architectural expression and technology used (not the realisation of a desired architectural expression)
- The influence of the human actor and the interaction between actors
- The influence of non-digital design tools

While Leach's digital tectonics has efficiently highlighted the range of digital possibilities that are offered to the tectonic tradition, it is still important to discuss the extent of the computer's ability in connection to the tectonic tradition while maintaining the complexity of the situation with many actors and other tools.

Where Leach shows that the digital tools have enabled an individual actor to work proficiently within one field, the current research discusses to which degree the digital tools enable the professionals to cross over the professional fields. As it was described in the methodology chapter, the collaboration is conceived as two fields with each their actors and design tools as it is seen in figure 9.

When the two professions engage in a shared architectural project they also share a field between the two professional fields. This field is only temporary and lasts as long as the architectural project does. This field is indicated by the dashed circle in figures 10 and 11. In this shared field the actors collaborate by engaging with the actors from the other professional field, building up a common habitus that allows the actors to interact and a common understanding of the goal of the project.

In this perception of the tectonic practice as a collaboration between two professional fields, the question about the computer as a design tool is set. Two models – figures 10 and 11 – describing the degree to which the design tools enable a tectonic practice are proposed.

The first model – figure 10 – describes one extreme where the design tool is positioned in the shared field and is therefore perceived to bridge the gap between the professions. Such a design tool could enable the architect to work with technical aspects and the engineer to work with aesthetic matters.

The second model – figure 11 – on the other hand, describes a situation where the design tools are positioned in the original professional fields. They do, however, not become a bridge between the professional fields. In this case it is not actually the design tool that enables a tectonic practice. Instead the collaboration that is necessary to create this kind of architectural quality is created by the actors involved. In this case the computer “only” enables each profession to work efficiently within each their field.

The two models may also supplement each other since the design tools could be ready-to-hand in some stages of the design process, but un-ready-to-hand in others. Through the case studies, these models will be used to describe the use of design tools, in addition to being used to discuss the degree to which the tectonic practice is enabled by the computer as a design tool.

The computer programmes that will be discussed fall in three groups. The first group is the computer programmes actually being used in the case studies. Secondly, a group of programmes being developed

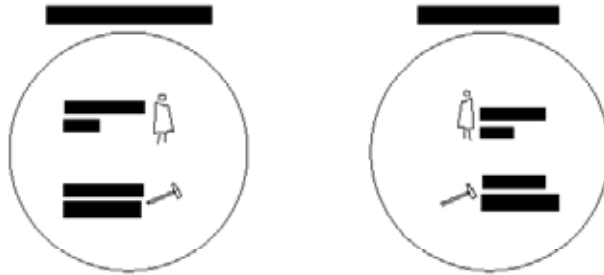


Figure 9: The professions are understood as each their field with each their actors (with different professional habitus and understanding of capital) and design tools.

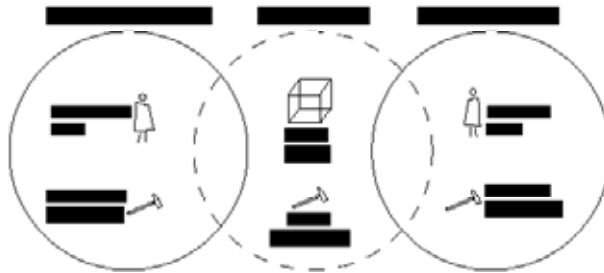


Figure 10: A situation where the (computer) design tool is part of the shared field and thereby serves as a bridge between the two fields.

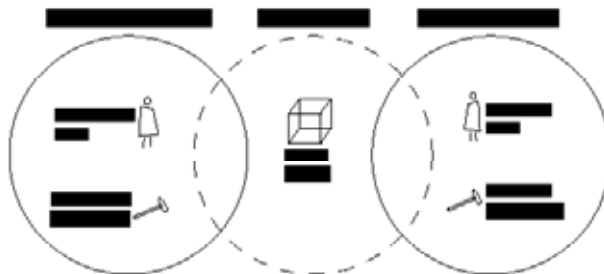


Figure 11: A situation where the (computer) design tools are supporting each professional field but does not serve as a bridge between the two fields.

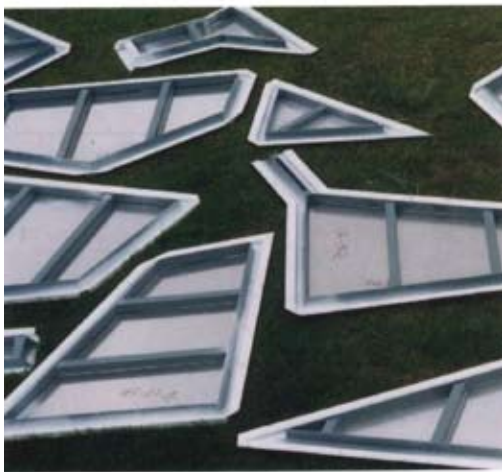


Figure 12-14: Assembly of the Serpentine Pavilion

from the field of acoustics is interesting to include because they demonstrate an attempt to support the early design development. Faist et al (1997) and Felmban and Oldham (2003) have proposed computer programmes that, however, have not caught on in the architectural environments because they all begin by limiting the architectural form to a shoebox-shape and thereby restricting the design too much. The third group discussed is being developed by Turner and Hall (1990) and Turner and Barnett (1998) and are likewise aiming at supporting the acoustic evaluation of early design proposals. In contrast to Faist, Felmban and Oldham's programmes these programmes maintains openness towards the design process. Neither direction in the development of acoustic computer programmes relates, however, to the concept of tectonics – this connection will be made on the basis of the broader understanding of the tectonic practice established through the case studies.

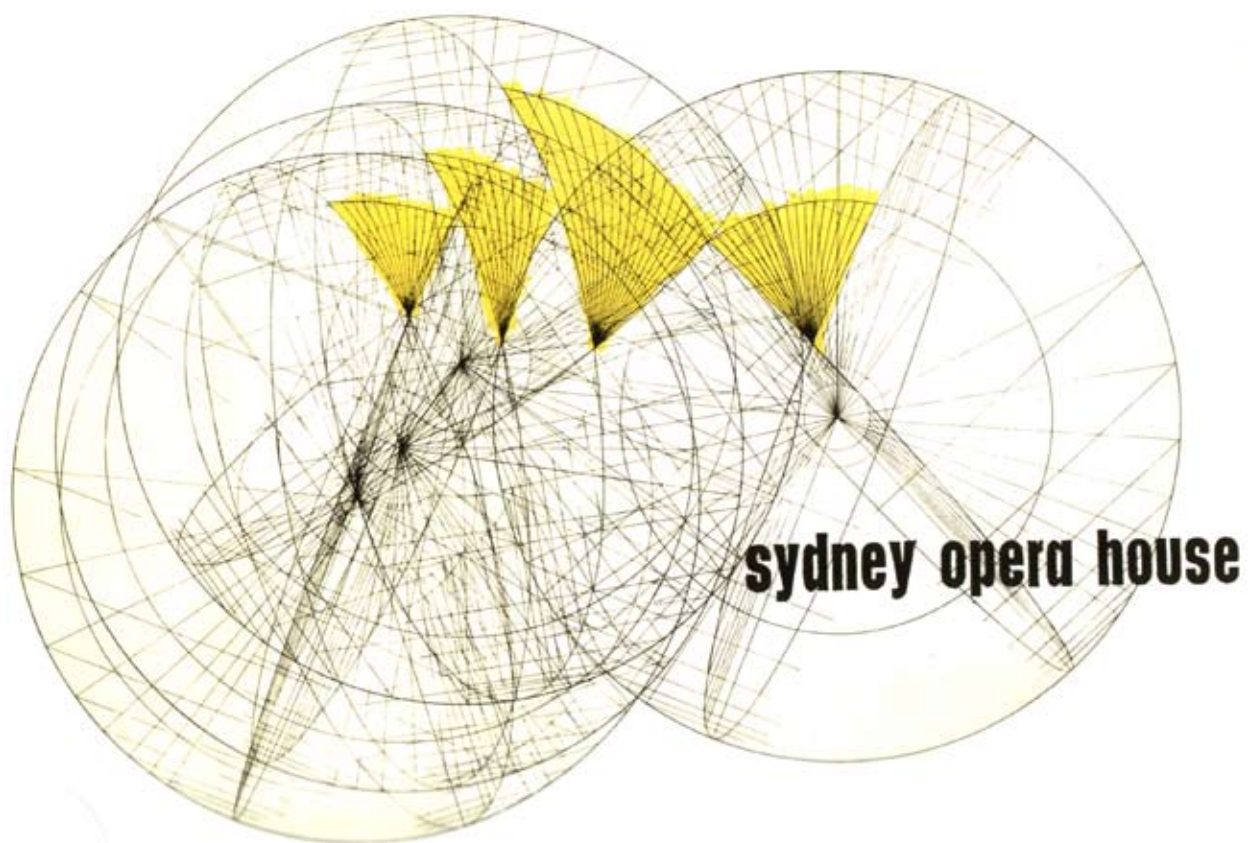
CONCLUSION

In this chapter the proposition that the computer holds a great deal of potential in connection with the tectonic practice was investigated. The concept of digital tectonic was analysed. It was found that the background for the introduction of the concept of tectonics in connection with digital architecture was that digital architecture is being constructed increasingly. In this construction digital architecture needs to address material, components and structural principles to a degree that was not necessary when digital architecture remained aesthetic experiments in the virtual world. The term tectonic is often used as a headline for these concerns, and it can therefore be said that the concept of tectonics in the digital era is often understood as another word for building.

The most developed understanding of the concept of tectonics in the digital era is found in the publication "Digital Tectonics" by Neil Leach et al (2004), in which it is argued that digital tectonics is a renewal of the Gothic tradition of using structural considerations for developing form. In this quest the digital can be used to generate a novel structural form. The technological novelty of the structural form that Leach points to is, however, limited and it seems that digital tectonics in this understanding is a new architectural approach, but with a traditional technological substance. In this quest the digital tools can support the structural solution of new architectural expressions. It was concluded that this understanding of digital tectonic has a number of shortcomings. As in the other conceptions of digital tectonics, this understanding points towards rendering the resolution between the technical and the architectural easier, but not necessarily to the development of an architectural culture of engaging with the technological substance of building as the basis of architectural expression. Further, this understanding brushes aside the gap between the professional fields and ignores the influence of non-digital design tools.

As another manner of approaching the investigation of the digital design tool in the tectonic practice, two models are proposed. The engineering and architectural professions are seen as distinct professional fields that have to collaborate in order to create tectonics. Furthermore, each profession has its own actors and design tools. The models describe two positions of the design tools – one where the design tools support each profession, and one where they support the shared field between the professional fields.

THE TECTONIC PRACTICE



sydney opera house

THE MINOR HALL CASE

While the concept of tectonics remains fundamentally the same, as it was argued in the last chapters, the role of the master builder is largely outplayed and the practice of tectonics has changed dramatically. The range of design tools available today is primarily digital tools. While the new tools may offer themselves as a new opportunity to the design of tectonic architecture, the degree to which they actually have an impact on the tectonic practice is still not sufficiently clarified because there is a lack of knowledge of what impact design tools have on the ability to design tectonics.

The two following chapters therefore take the investigation of the design tools into an actual tectonic practice situation by following design processes and their dependency on design tools. The investigation will focus equally on the actors and the tools in the design process, and the aim of the case study research is to expose to what degree the individual actor (consultants and architects) and the various design tools (including computers) can be seen as enabling or obstructing the tectonic practice.

The case study chosen for investigation is the Sydney Opera House with a focus on the design development of the acoustic auditoria. The criteria for choosing this project as the case study was, as mentioned in the methodology chapter, (1) that it is a tectonic project and (2) that it spans from the pre-digital to the digital era. While the second criterion is confirmed by the mere fact that the case spans from the pre-digital to the digital era, the first criterion calls for more attention. As an introduction to the design process of the auditoria of the Sydney Opera House, the project as a whole will be described to argue why the auditorium project can be expected to be tectonic because of its role as a part of a tectonic building project.

The Opera House – a tectonic case

In 1957 the relatively unknown architect Jørn Utzon won the international competition for a new Opera House in Sydney. Utzon's competition proposal was characterised by a very conscious reading of the site. Bennelong Point is situated in a central point in the Sydney harbour and would therefore be viewed from all angles – including from above. Utzon had therefore envisioned the Opera House as a sculpture that was to relate to the sails of the boats in the harbour rather than the buildings of the city.

The customary approach of Utzon's contemporaries was a strong functional approach where it was attempted to portray the function of the buildings through the architectural expression. The time was also characterised by a suspicion towards any curved forms. These were understood as an expression of the architect's own subjective aesthetic preferences while the right angles were understood as rational and neutral. The Sydney Opera House broke with all these rules. Instead of expressing the function of the Opera House bluntly by letting the stage tower protrude through the roof, Utzon expressed the function in a more subtle manner by letting the sails of the Opera House reflect the different heights of the stage towers and the auditoria. Likewise the concept of letting the two main auditoria sit as free objects below the curving sails and thereby build a room within a room was a break away from the Modernist dictum "less is more" that Louis Sullivan coined in the beginning of the twentieth century. Instead of reducing the building to its functional core, Utzon created a solution with a greater emphasis on the human experience and therefore developed the building as a series of experiences that the visitors would encounter on their way from the city to a performance in the building. The ascending of the platform, the three dimensional sculpture

created by the billowing sails as well as the curved shape of the auditoria were all part of building up expectations that would culminate with the performance in the auditoria.

The Sydney Opera House is widely recognised as a tectonic masterpiece (Frampton, 1995 and Fromonot, 1998) and Utzon's tectonic approach is evident in many parts of the Opera House project. In the overall composition of the project there is a clear division between the platform and the light sails demonstrating a conscious use of materials; the heavy base that strives towards the ground holds the pragmatic functions of backstage and office spaces while the sails encapsulating the performance spaces strive to the sky and rightly becomes the focal point of the composition.

"The audience and the performance itself, all taking place on top of the plateau, should be covered with a "light" sculptural roof, emphasising the heavy mass of the plateau below." (Utzon, 2002, p. 9).

Utzon's use of platforms as a plateau for human activity was inspired by the Mayan temples in Mexico and was a one of the earliest reintroductions of the plateau as an element in the modern architecture while the sails were inspired by the contemporary concrete technology. The geometry of the sails were from the outset of the project the main concern of Jørn Utzon as well as Ove Arup who worked as structural engineer on the project. Due to political concerns the construction needed to begin quickly after the competition. The project was divided into three separate stages; the podium, the sails and the interiors and while the design team was still working on a solution for the geometry of the sails, the construction of the podium began in 1958.

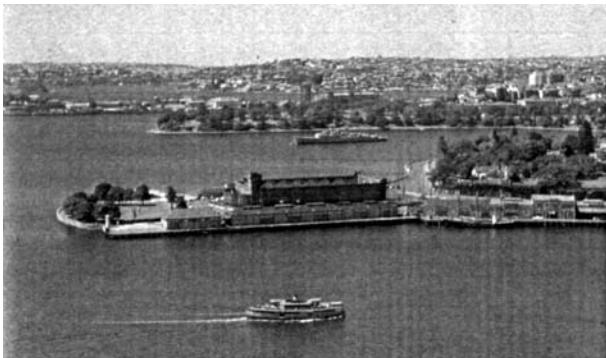


Figure 1: Bennelong Pier housed a tram shed before the Opera House



Figure 2: The concourse beams

The investigation of the tectonic practice of Jørn Utzon will focus on stage three – the interiors - but this investigation should pause for a minute on how the rest of the Opera House project was tectonic in order to understand Utzon's general tectonic approach as a background for the development of the Minor Hall. To understand the tectonic quality of the Sydney House project, the three stages of the building project serve as separate examples of tectonics.

The platform was the first to be built. The concourse beam is one of the most fascinating structural designs in the Opera House and testifies to the happy collaboration between Arup and Utzon. While the competition project displayed a concourse supported by columns, Arup and Utzon decided to develop the concourse beam in a manner that would render supports superfluous. The concourse was developed to take advantage of the compressive strength of the concrete and therefore has cross-sections changing from a U-shape into a T-shape reflecting where the compression forces are greatest. This creates a direct reflection of the forces running through the structure as well as a very expressive structure with beautifully twisted surfaces. In terms of the three tectonic approaches described earlier, the concourse is therefore a good example of Materiality and Technique and Building Principle. The Materiality and Technique in creating the formwork has clearly influenced the expression as well as has the development of the long span without columns as a Building Principle.

In opposition to the concourse as a successful tectonic solution, the sails were more problematic. The competition project reflects Utzon's fascination of the contemporary concrete technology where shell structures were refined to very delicate and thin concrete constructions. Utzon drew the sails of the Opera House with this technology in mind but

the pointed profile of the arches and the little support that connected them to the ground rendered them unable to stand as shells. Jack Zunz confirms that this came as a surprise to Utzon "His pointed, ogival arches were, contrary to his expectations, unable to sustain by membrane action alone the forces to which they would be subjected..." (Zunz, 1988, p. 5) and even the assessors of the competition expected that the shell technology would be the right solution;

"It should perhaps be stated that the technique of building shell vaults has now been developed in many countries of the world... The use of this form of construction seems to us to be particularly appropriate." (Ashworth et al, 1957).

The pointed shape of the sails was maintained despite this realisation and made possible through a ribbed structure and a tie-beam beneath the podium instead of the smooth, self-supporting shells that Utzon had originally conceived. The sails are examples of tectonic design but not in terms of the Building Principle - the shape of the sails does not contribute to the structural solution of them. Instead, the sails should be considered tectonic due to their brilliant solution with respect to component and composition. In conceiving the sails as a building system with only 14 individual elements, Utzon demonstrated his masterly understanding of the strength of the industrial era. As he commented himself,

"You will see that I have succeeded in getting these great complicated forms under control and under control still with the freedom of the craft, paired with the precision of the machine age." (Utzon, 1965b, p. 49).

As a footnote it should be remarked that the design of the sails also demonstrated that the Opera House project is positioned in a time of transition between the pre-digital and the digital era since the Sydney Opera House project was one of the first building projects ever to take advantage of the computer in the calculation of the sails as a three-dimensional structure.

While the first two stages of the Opera House project – the design and construction of the sails and podium - are extensively researched and published, the un-realised interiors of the auditoria are less known. This makes them interesting in their own right but from a tectonic point they are even more interesting. Because the auditoria were the last of the three stages in the design, Utzon had already developed a clear sense of tectonic design and had, as described, equally good and bad experiences with his tectonic approach. In the auditoria Utzon had the opportunity to connect the threads of what he had learned – this confirms the Minor Hall as a tectonic project which was the criteria that the case was chosen from. In the following, the tectonic practice of Utzon, as it took place in the design development of the Minor Hall, is described with a focus on the actors and design tools.

Getting valid information about a controversial project

"...not the least of the surprises about Sydney is that unquestionably the most popular, and arguably the greatest, public building of the twentieth century is accorded little – and in some cases no – space in well-known histories of modern architecture" (Weston 2001, p. 114).

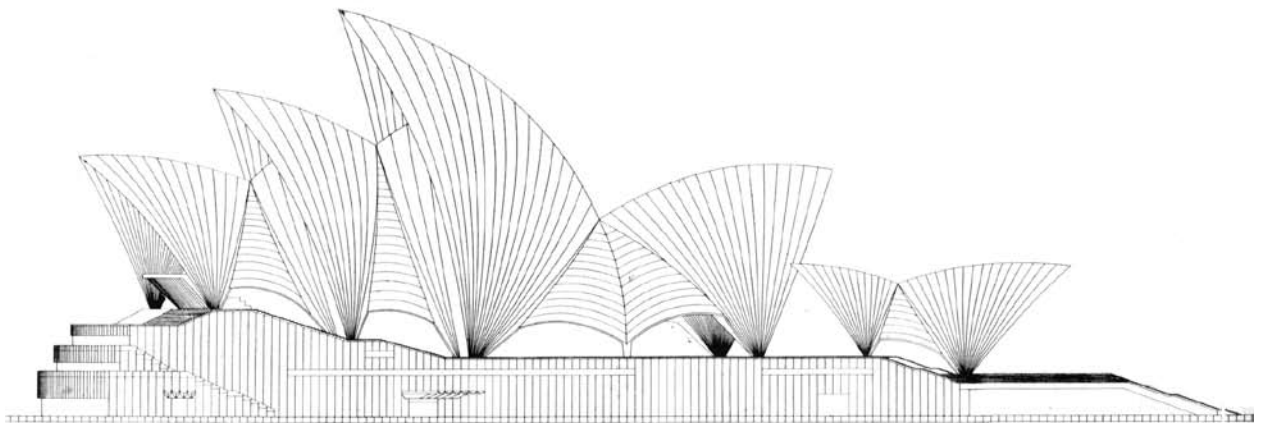
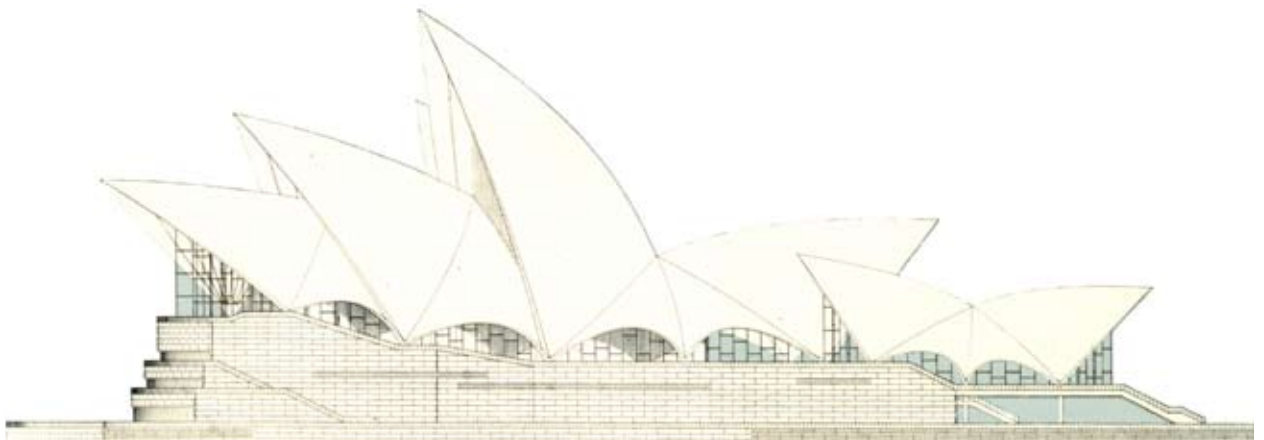
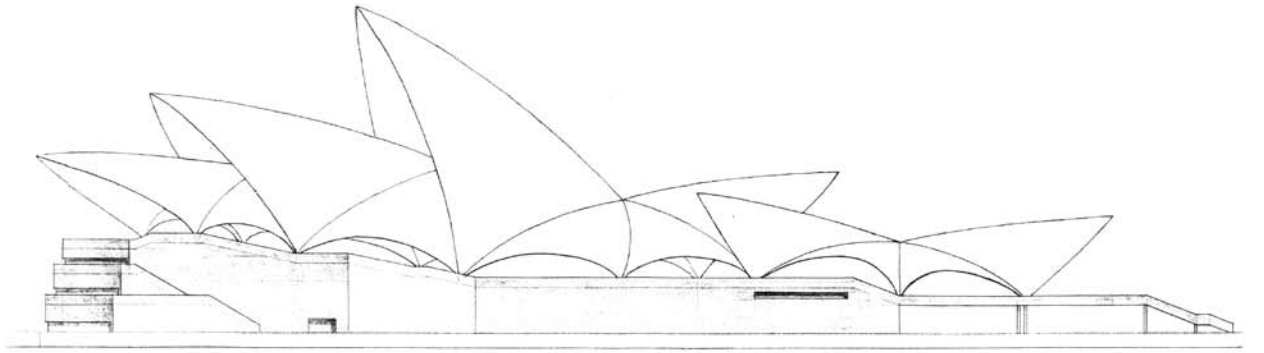


Figure 3-5: Development of the Opera House sails. Competition proposal sails, edited sails, at the bottom the realised sails



Roughly the publications on the Sydney Opera House and Jørn Utzon as an architect can be understood in three periods. The first period after Utzon won the competition was characterised by a great interest in Utzon and the competition project as such. In this period Utzon was presented as the new genius and hope for the architectural profession due to his refreshing approach to industrialised architecture. (Ashworth et al, 1957; Jørn Utzon's Visit to Sydney, 1957; Sydney Opera House Competition, 1957; Keys, 1965; Giedion, 1965). The praise of Utzon's architecture as a new potential for modern architecture is especially evident in the essay by Giedion, where Utzon is proclaimed to be a front figure of the 'third generation' of modern architects. From this period is – naturally – also a number of original documents from the design process (Minutes of meetings, 1958-1966; Utzon, 1965a, 1965b).



In the second period a much more polarised understanding of Jørn Utzon as an architect arose due to his resignation/dismissal from the Opera House project. Most publications were critical (Baume, 1967; Yeoman, 1968; Hall, 1968; Jordan, 1980) and many of these critical voices focused on the soap opera potential of the story rather than the architectural quality of the project – examples of this is Yeoman and Baume. Other publications from this period defended Utzon and his work on the Opera House project (Duek-Cohen, 1967; Carter, 1967) and argued that "Utzon, in short, is clearly the most suitable person to finish the job. He should be invited to return and finish it." (Duek-Cohen, 1967, p. 42).

Between the second and third period there was a long gap where only a few very dedicated writers were interested in Utzon and his work. The third period began in the nineties and was characterised by recognition of the architectural and cultural value

Figure 6-7: Components are cladding the sails

of Utzon's work – especially caused by the success of the Opera House as an icon for Australia (Clouds: Jørn Utzon, 1994; Drew, 1995; Frampton, 1995; Goad, 1997; Fromonot, 1998; Drew, 1999; Weston, 2001; Mikami, 2001; Keiding, 2003; Nobis, 2003). The writings from this period are primarily concerned with the architectural quality of the building as realised. Recently, a renewed interest is fuelled by the re-engagement of Utzon by the Opera House. This will be commented on later in connection to the contemporary part of the case study.

Within the wide range of sources available, this research leans on the original documents as well as the publications from the third period. The original documents offer a unique insight into the actors of the case and are not accessed through another author's interpretation. Apart from this concern with letting the actors speak for themselves, another concern guided the choice of sources. This was the creation of a consistent narrative with enough information to support an analysis of the case. The research interest in the design development guided the choice of sources and ruled out sources such as Baume, Yeoman and Duek-Cohen who are not useful due to a lack of information of the specific design development as well as their overly partial outlook. The sources chosen to cover this side of the narrative are therefore the works from the third period and primarily the writings of Philip Nobis, Richard Weston and Françoise Fromonot. Especially Philip Nobis, who goes into great detail concerning the design development of the acoustic interior, is used extensively.

MINOR HALL DESIGN DEVELOPMENT – THE UNREALISED INTERIORS

The competition entry for Sydney Opera House from Utzon was in the words of the competition assessors "...simple to the point of being diagrammatic" (Ashworth et al, 1957). This also applied to the auditoria even though the auditoria were probably the most developed of the design proposal. The competition brief asked for a Major Hall which should primarily cater for concert recitals for an audience of 3000 to 3500. A secondary use for the hall was to be large-scale opera, ballet, dance, choral works, pageants and mass meetings. The Minor hall was primarily to be used for drama, intimate opera, chamber music, concerts, recitals and lectures and seat around 1100 (Nobis, 1994). In effect it was therefore two multipurpose halls that functioned acoustically for music as well as speech that the Opera House Committee had asked for.

The plans submitted for the competition by Utzon shows the two halls sitting side by side in the podium, each carved into the podium like Greek theatres into a mountain side. The layout of the plan also resembles Greek theatres with circular steps sharing a common centre and focus point at the centre of the stage.

No acousticians were involved with the design of the auditoria even though Utzon got advice with regard to the accompanying text (Jordan, 2004), but Utzon would have searched for inspiration to the shape of the auditoria among contemporary auditoria. The plan of the Opera House thus resembles the radial plan that Aalto often used as outdoor gathering places as well as in his acoustic spaces - for instance the Culture House in Helsinki that was initiated in 1952.

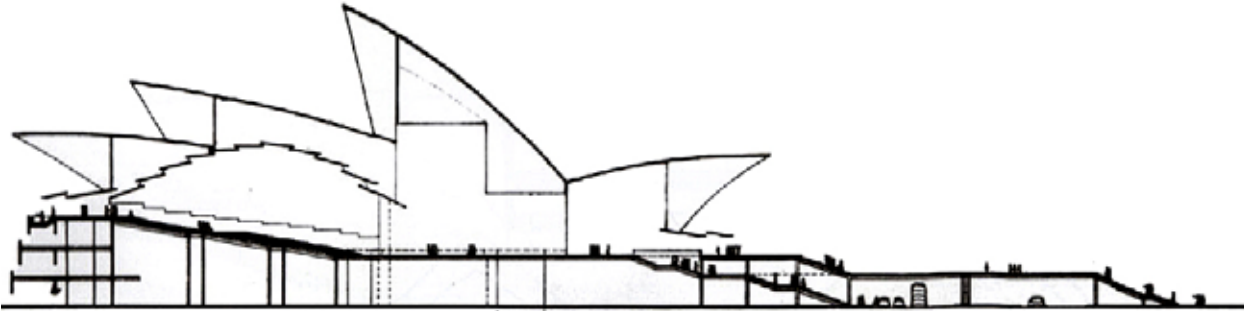


Figure 8: The reflecting ceiling of the halls was indicated in section of Utzon's competition project

The ceiling profile of the competition project by Utzon does not resemble Aalto's Culture House but there are plenty of other contemporary auditoria that Utzon could have been inspired by in this respect. He would have been aware of the Royal Festival Hall in London from 1951 that was designed by Leslie Martin – who also happened to be one of the judges of the competition – and he would naturally have known the Radio House in Copenhagen by Vilhelm Lauritzen from 1941 that could have inspired Utzon to work with wooden reflective elements. Both halls have a ceiling profile that is similar to the one Utzon drew in the competition proposal. In addition, the acoustic principle used in the Sydney Opera House is similar to the one used in the Festival Hall. The acoustic principle is often referred to as “an egg in a box” because the auditorium is placed as a separate spatial entity, an “egg”, within the building. Thereby the “box”, the outer structure, shields the transferral of noise from outside through the structure.

For these reasons, it seems likely that Utzon had studied a number of contemporary architectural references to draw the competition proposal for his Opera House. The manner in which he transformed the inspiration into his own design, however, suggests that he only had a vague understanding of the acoustic principles behind the architectural references. On one hand he seems to understand the “egg in a box” principle enough to design the Sydney Opera House from it. On the other hand, he suggests the auditoria as flexible structures with side walls that were able to open during some performances. This suggestion would have been very difficult to realise because the auditorium acoustics needed the reflections from the side walls to develop. The assessors, among whom at least Leslie Martin had experience in designing auditoria, commented on the proposal in their report,

“There are many points on which we are bound to comment. There is, for example, the author's conception that the walls surrounding these auditoria could be entirely opened up....In our view, for the majority of the performances, the movable walls which he has shown on section would need to be closed.” (Ashworth, 1957, p. 275).

It is fair to conclude that Utzon was inexperienced in acoustics in the beginning of the Sydney Opera House project – but this changed through the project.

Utzon seeks acoustic design advice

After having won the competition in 1957, Utzon immediately began work by gathering a team of advisers and collecting their reports in a document known as the Red Book. In the field of acoustics the Danish acoustician Vilhelm Lassen Jordan was hired. The advice from Jordan was highly needed but the collaboration between Jordan and Utzon was troublesome.

For the next years Utzon and Ove Arup, the construction engineer, were fully occupied with the construction of the podium and the sails, and it was not until after the Red Book (from March 1958), that Utzon became more involved in the design of the halls. The halls showed in the Red Book were therefore primarily done by Jordan which Jordan himself hints at,

‘Without analysing the cooperation between architect and acoustician too minutely, it is fair to say that regarding this first design, the acoustician was responsible for many suggestions.’ (Jordan, 1980, p. 95).

Likewise, Utzon’s own account of the design development does not even include this preliminary proposal (Utzon, 1965a). Jordan was inspired by the traditional technology in acoustics which was the classic auditoria shapes. The drawings for this first proposal consequently showed a hall that was as close to a shoebox shape with flat ceilings and walls as possible within the geometry of the sails. Especially Jordan introduced parallel sidewalls in order to ensure that the sound from the stage was reflected into the hall. Jordan describes the halls quite dryly in the Red Book,

“The proportions of the area are 2:6:7 (mean height: mean width: depth), which is appropriate for a typical theatre hall, where the stress is laid more

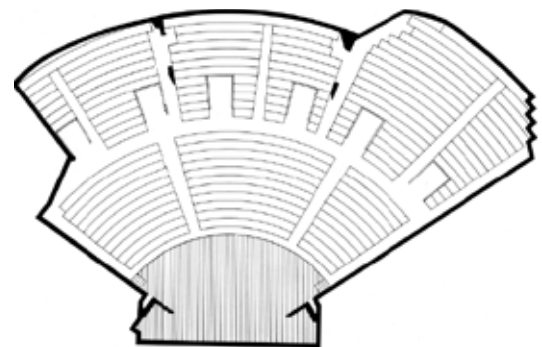


Figure 9: Plan of Alvar Aalto's House of Culture in Helsinki

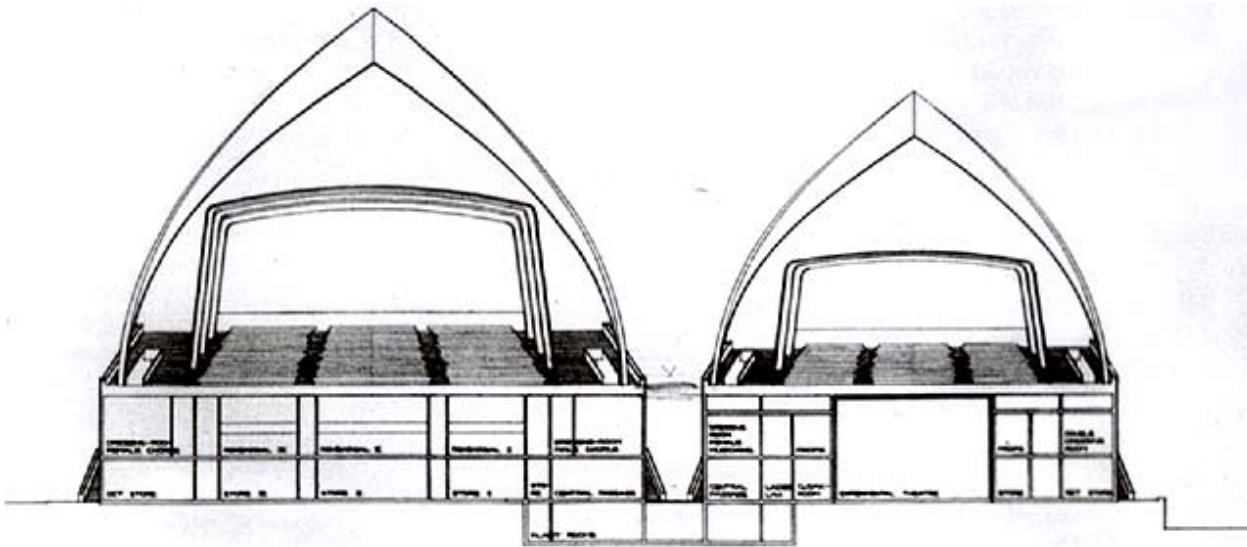


Figure 10: Section of the Red Book proposal

upon definition than reverberation.” (Nobis, 1994, p. 33).

From Jordan’s point of view the design was solved with the proposal in the Red Book; the required number of people was seated in an appropriate room with the desired room acoustic quality. From Utzon’s point of view, however, the Red Book was not what he wanted for the Sydney Opera House. The shoebox shaped proposal would not only have been difficult to fit under the sails, it would also stand out in comparison to the organic shape of the sails. In contrast to Jordan, Utzon did not want to work from the traditional technology of the classic halls. Instead, he needed to develop a new architectural approach with a new technology.

An architect’s understanding of sound

After the Red Book was handed in (March 1958), Utzon got more involved with the auditoria design, in an attempt to understand the fundamentals of acoustics and thereby design an alternative to Jordan’s rectilinear shaped auditorium. In a meeting in mid-1958 Jordan was asked to explain some of the fundamentals of acoustics to the architects. He explained how the volume is determined by the shape and functionality of the room and commented on the shape of the surfaces (Minutes of meetings, 30.6.1958).

With this newly gained understanding of acoustics, Utzon and his employees in August 1959 developed a scheme for the Minor Hall that they called the stepped cloud scheme. As the name suggests, it was inspired from the shape of clouds – a re-occurring inspiration for Utzon – and was intended to float like a cloud over the podium by being suspended from the sails of the opera. Another inspiration for the hall was the movement of water as Utzon’s former employees Yuzo Mikami, who drew the proposal, recalls,

"Jørn asked me to work on the new design of the Minor Hall auditorium. He took me to a nearby seashore by the Sound in Hellebaek, where the gentle movement of water formed the ridges of waves one after another. The continuous ridge went up higher and higher as it came nearer to the shore, and finally the crest of the wave began to break, overriding the ridge and coming down with a drumming sound onto the wet sand on the beach. We watched the movement of the waves for quite a long time. It was very dynamic and breathtakingly beautiful. Every one of the waves showed a different character in its movement. Jørn said, 'Yuzo, can't we design the ceiling of the Minor Hall something like that?' whilst looking at the breaking crest of the waves." (Mikami, 2001, p. 118).

The new scheme of the Minor Hall was conceived as closely related to the organic geometry of the Opera House. Where the plan and the section of the auditoria in the competition proposal were somewhat incongruous, the stepped cloud scheme attempted to create a harmony between the two. In a later tv-interview with Pi Michael (Cloud: Jørn Utzon, 1994) Utzon described how he wanted the auditoria to fit under the sails like walnuts. Both the nut and the shell of a walnut have undulating shapes – they are closely related but still different and this close relationship between outside and inside was what Utzon used the walnut analogy to explain,

"When you see a walnut... it has a wobbly form. When you then open it up, it is quite logical that the nut itself has the shape that it does." (Clouds: Jørn Utzon, 1994).

The new scheme consisted of segments spanning from the proscenium and ending in a large concave curve in the back of the hall. The segments consti-



Figure 11: Model of the 'stepped cloud' scheme

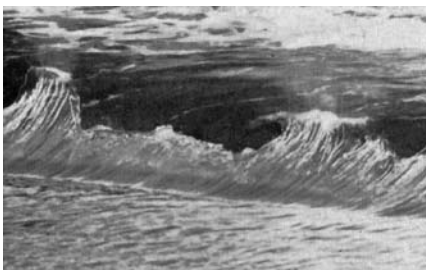
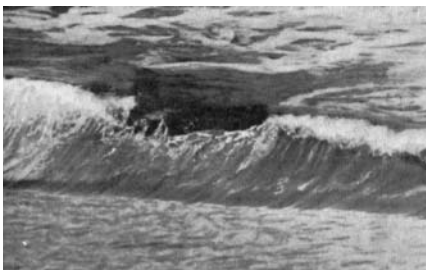


Figure 12: Waves was a major inspiration for the stepped cloud proposal

tuted not only the ceiling but the walls of the auditoria in one continuous form. The shape of the auditorium ceiling now followed the plan because it similarly radiated from a centre point on the stage. This idea had the same logic as the plan that was also meant to focus the attention of the audience towards the stage, to where the sound was coming from. Also the stepping segments of the auditoria had the effect that the entrances to the hall could be hidden from the eye of the spectator during the performance. Utzon described the effect, "...therefore, for the eye of the seated spectator the theatre appears absolutely closed, even when the doors are actually open" (Utzon, 1965a).

One of the most important aspects of the design of the halls was that the experience of the halls should support the whole opera house experience. The rising up the stairs, the entrance into the southern foyer and following the shape of the halls under the sails to the entrance of the halls were all part of building up to the climax; the performance in the halls. To Utzon the relationship between the sails and the halls was therefore of uttermost importance because the hall would be seen from the outside sitting under the sail.

"... the two halls hang from the shells visibly as a piece of furniture from the outside, and ... the halls and the stage tower in forms and colour will stand out like a big exotic bird ..." (Utzon, 1965b).

Utzon saw the auditoria as pieces of furniture in more than a figurative sense; he intended to build the curves out of plywood. The formwork for the concourse beam had been constructed from plywood and had led Utzon's attention to Australia's leading position within this technology. In Australia he met with Ralph Symonds who had developed an innovative method for rendering plywood structurally rigid by creating a sandwich construction with a layer of lead between two layers of plywood. This material was perfect for the auditoria because it could create the sound insulation, the structural rigidity and the reflections needed in one integral move. In the tectonic aspect of Materiality and Technique Utzon's thinking of the auditoria was therefore already tectonic in its outset.

From an acoustical point of view, however, the stepped cloud scheme was not advantageous. The large concave curve of the ceiling in the back of the room would result in focusing of sound thus creating high concentration of sound in some areas and a lack of sound in others. With this lack of acoustical quality Jordan cannot have participated much in the conception of the scheme and it was clear that Utzon's main interest in the stepped cloud scheme was the harmony with the rest of the Opera House. His investigations into the hall were primarily concerned with the form of the auditoria as a sculpture in its own right and not as a tectonic Building Principle. During the course of he had plaster models of it cast in order to be able to develop the composition.

While it was clear from the stepped cloud scheme that Utzon lacked a technical understanding of acoustics, it also seems from the shape of the scheme that he could have studied further architectural references – for instance the undulating ceiling seems to be inspired by Aalto's Viipuri Library as well as the segmented side walls seem to have close connections to Erikson's concert hall in Göteborg from 1935.

Aalto's design of acoustical spaces in Viipuri Library and Vouksenniska Church was a source of inspiration

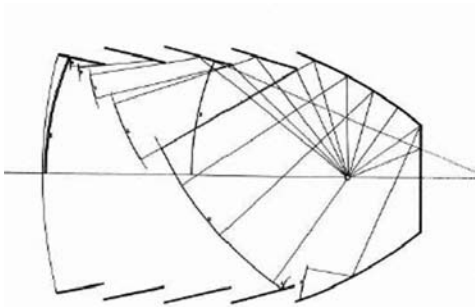


Figure 13: Erikson's concert hall in Gothenburg

to many architects and probably also to Utzon who, as mentioned, was a great admirer of Aalto. However, as Jones and Kang argue (2003) the inspiration from Aalto's undulating ceilings was - from an acoustic point of view - unfortunate. Beautiful as it is, the undulating ceiling in Viipuri does not benefit the acoustic quality of the room apart from covering a collection of beams that would have produced undesirable reflections. In a room without such beams Aalto's undulating ceiling would therefore not be a relevant reference.

Utzon's use of architectural references and conceptual analogies did, then, not help him in his quest to create tectonic architecture in the Building Principle approach. While he succeeded in creating a shape that related well to the form of the cavity under the sails, he failed in creating a scheme that was well functioning in acoustical terms. Through the development of these first schemes it is clear that neither actors nor design tools enabled a tectonic practice. Neither Jordan's scientific approach to acoustics reflected in the Red Book proposal nor Utzon's architectural approach to acoustics reflected in the stepped cloud proposal helped bridge the gap between the professions in order to create a scheme that solved the acoustical requirements inherent to the architectural language.

Jordan's hesitance on design

The lack of applying acoustic principles in Utzon's first proposal to the Minor Hall did not present an immediate problem - it could be seen as a step on the way to develop an architectural language for the auditoria that in a further development could incorporate acoustical concerns to be an inherent part of the architectural language. The further development of the case, however, shows that it was not as easy for Jordan and Utzon find a common approach and it points to the significance of the actors (as opposed to the design tools) in enabling a tectonic practice. The first drawing of the stepped cloud scheme occurs in August 1959 (Nobis, 1994, p. 31) and the following three years the scheme was developed extensively.

Jordan had not been involved with the design of the scheme and he was very hesitant on commenting on the proposal. A response from Jordan to the stepped cloud scheme is not found in the minutes of meetings - whether it has been lost from the archives or whether Jordan really did not comment on the obvious acoustical difficulties of the scheme can only be speculated upon. Jordan's son and partner, Niels Jordan, recalls the situation as Utzon stopped asking for advice (Jordan, 2004). In retrospect, however, Jordan was not hesitant on commenting on the project and describes the development as such,

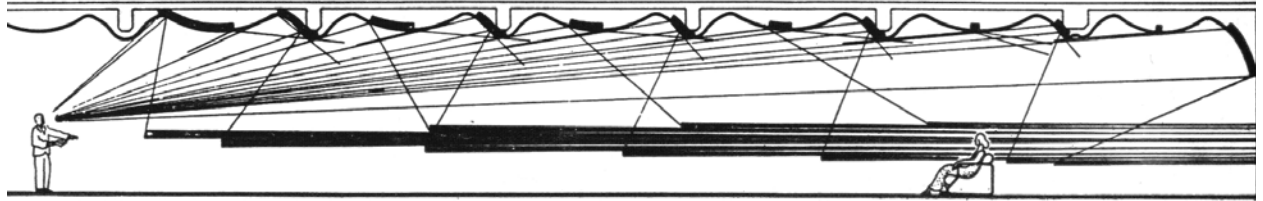


Figure 14: Acoustics analysis of Viipuri Library

"In his approach to the design, the winner of the competition (the Danish architect Jørn Utzon) was obviously influenced, primarily by the simplicity of the Greek amphitheatre but also by some profoundly personal ideas, indeed sculptural conceptions, which were original to the point of being revolutionary in architecture, but which, unfortunately, had absolutely no association with the classical design of concert halls." (Jordan 1980, p. 92).

While Utzon had been more concerned on an architectural than a technical understanding of acoustics in the development of the stepped cloud scheme, it seems that Utzon subsequently was eager to understand acoustics. For instance Utzon continually asked for more information to understand acoustics – one example of this is in 1960 when he asked Jordan for "a list of literature dealing with acoustical problems" (Minutes of meetings, 17.11.1960).

Primarily Jordan's hesitancy can be explained by his traditional approach to the acoustic technology. Like many other acousticians Jordan worked from the classic auditoria and therefore Utzon's design (being far from any precedents) was difficult for him to support. What he could do, however, was to evaluate the acoustic quality of Utzon's design with a tool he had pioneered himself – the scale model testing. In order to acoustically test the proposal with the scale model, the scheme needed to be fully developed with accurate geometrical information. This design tool was as such ready-to-hand in the evaluation stage of the design but it had the disadvantage that it could not support Utzon's design development.

Utzon, however, had difficulties in understanding this hesitancy of his consultant and clearly searched for information on acoustics so that he could develop his scheme with respect to acoustics as well as other architectural concerns. In this context he described Jordan's hesitancy as a sign of despair, "The first acoustical engineer to participate in the project was Dr. Jordan. He gave up at a certain stage when we came up to a dead corner with Minor Hall..." (Utzon, 1965a, p. 9). Only in 1961, after almost two years of design development on the stepped cloud scheme, does Jordan comment that he "agreed on the shape of MI-hall subject to minor modifications" (Minutes of meetings 16.03.1961). Still he needed to build a scale model and test it in order to advise exactly which modifications were necessary.

Jordan's hesitancy in commenting on the stepped cloud scheme can be argued to be caused by the design tools available at that time - the inconvenience of the scale model testing that needed a large amount of

details and took a long time obstructed a tectonic practice because Jordan relied on it to give adequate advice to Utzon. However, it was not only the design tools available but also Jordan himself as an actor that obstructed the tectonic practice. The following crucial development in the case underlines this by describing how other actors with the same design tools available could enable a tectonic practice.

The stepped cloud scheme was presented in the Yellow Book, given to the Australian Government in February 1962 and was, despite its acoustical difficulties, accepted.

New consultants and new design tools

On Utzon's return from Sydney, where he had presented the Yellow Book, he went to Berlin and Vienna. Utzon had read about the Berliner Philharmonie where the architect Hans Scharoun and the acousticians had introduced a completely new geometry to auditorium design. This auditorium was thus an example of a new architectural approach and a new technological approach to acoustics. He contacted Lothar Cremer and Werner Gabler who were the acousticians on the project and met with them in Berlin. The partners were very experienced in the design of concert halls and had completed a number of them throughout Europe. Lothar Cremer was one of the most important acousticians of this century and professor at the technical university of Berlin while Werner Gabler was an architect specialised in acoustical spaces. The collaboration with these two Germans was to become very influential to Utzon.

The meeting in Berlin is recorded in the minutes "Jørn Utzon explained the drawings for the Sydney Opera House. It was decided that Mr. Gabler and Professor Krämer should, with the help of a model, test the acoustics in the Sydney Opera House together with Dr. Jordan or as a second opinion." (Minutes of meetings 02.06.1962). In Berlin Utzon was also introduced to two rooms – one with only absorptive surfaces and one with only reflective surfaces which helped him to understand how the modern acoustic rooms functioned through reflective surfaces instead of through direct sound as the Greek theatres (Utzon, 1965a).

From this meeting it is already evident that the habitus of these consultants was different from Jordan's. Even though Cremer was a well-respected scientist his acoustic expertise could be translated by Gabler who bridged the professions by being an architect as well as a specialist in acoustics. Gabler could relate to the habitus of the architect and Utzon's acoustic illiteracy and therefore instruct him in the fundamental elements of acoustics. Also he had an intimate understanding of the architectural process and would have known what would be necessary for Utzon to understand in order to begin designing a Building Principle that solved the acoustic requirement. Jørn Utzon's son Jan Utzon confirms this difference between the consultants,

"I think my father found out that the German company, Cremer & Gabler, had developed a technique, which was useful in connection with the very complex halls in Sydney, and therefore he consulted them too. (...) My father needed someone with a better understanding of irregular spaces, whereas Jordan was more old-school..." (Utzon, 2006, I. 362-369).

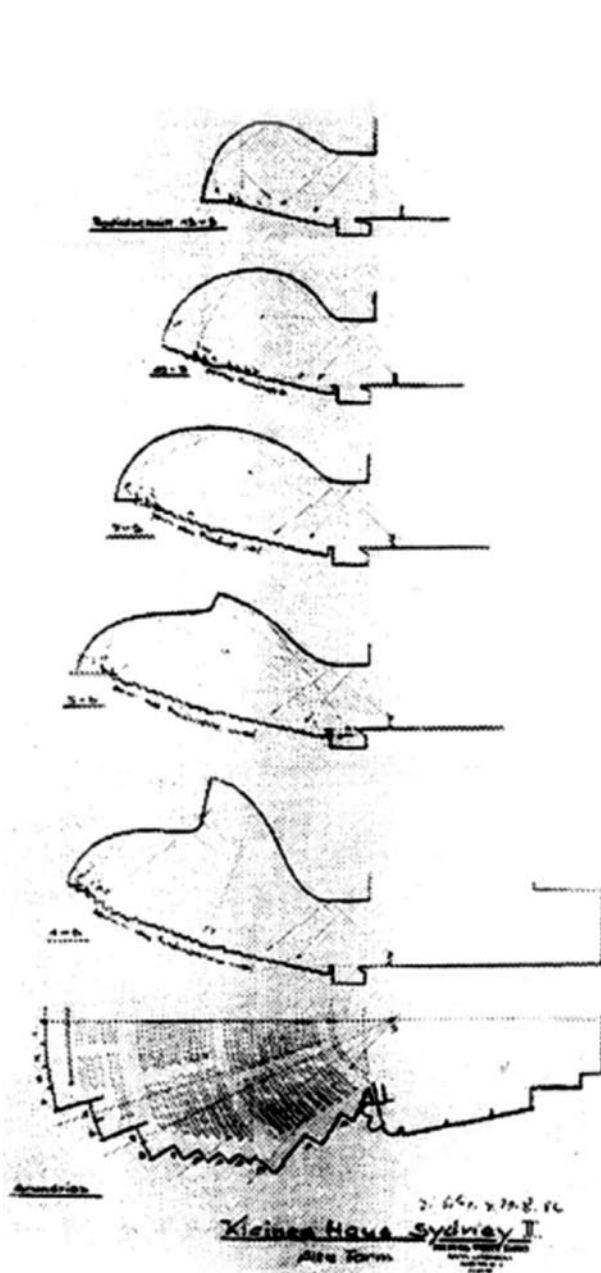


Figure 15: Letter from Gabler to Utzon - diagrams explaining focusing effect of concave ceiling

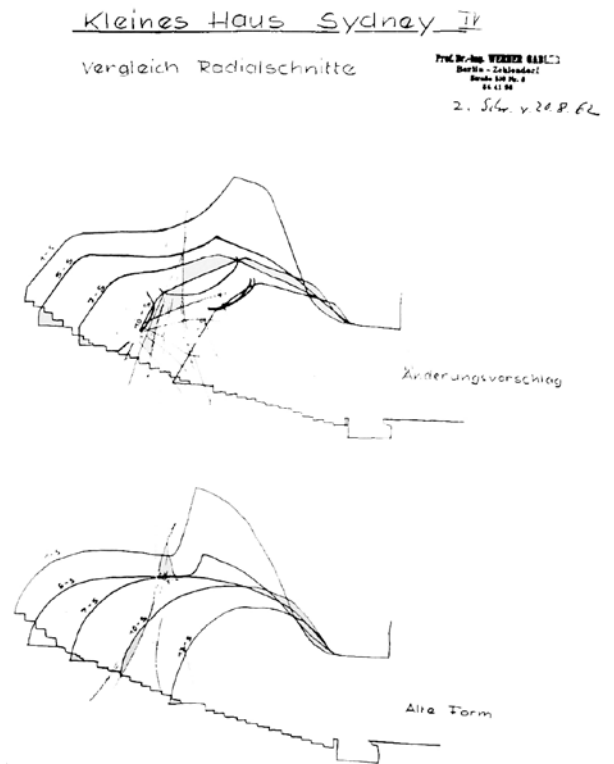


Figure 16: Letter from Gabler to Utzon - diagrams suggesting to change the ceiling curves from concave to convex

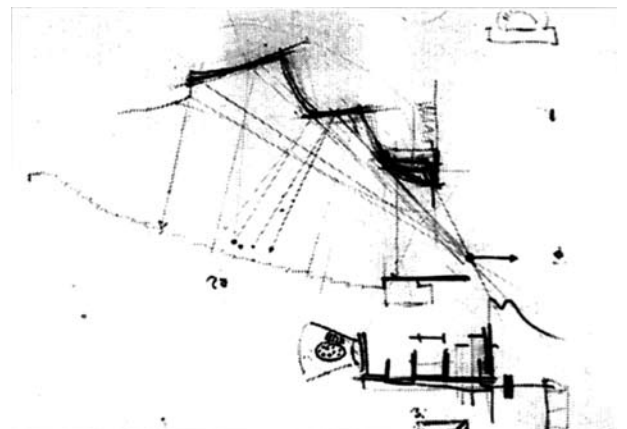


Figure 17: Sketches by Utzon showing investigations of reflection lines

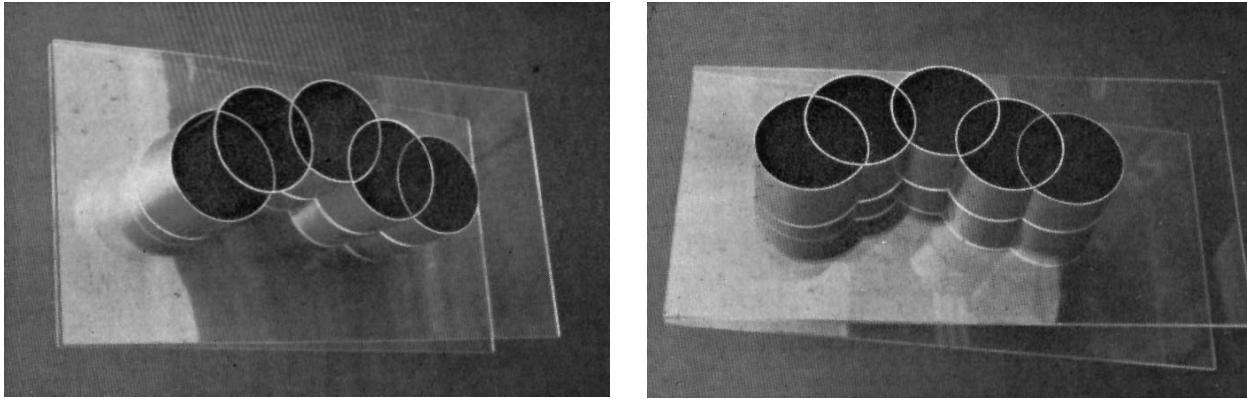


Figure 18-21: Illustrations showing the principle of the curved, segmented ceiling. One segment of the ceiling is described by the geometry between the slanted sheets of perspex and the lower side of the metal circles.

Both of the new consultants were sent drawings of the stepped cloud scheme in August 1962. Cremer responded quickly,

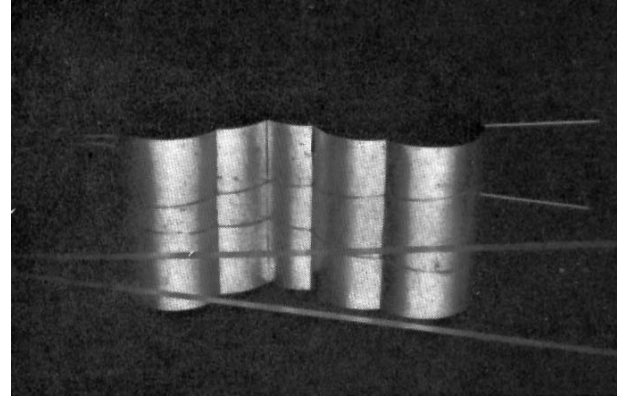
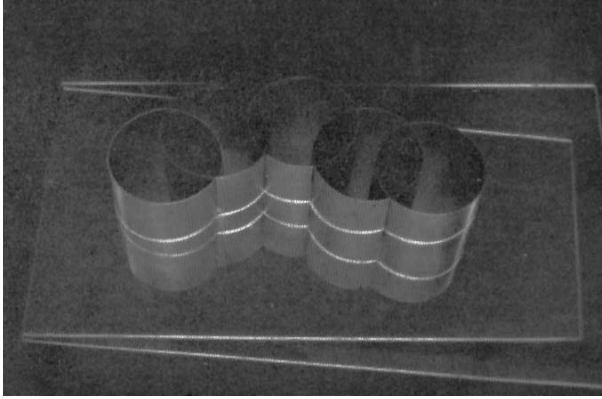
“The large radius concave curvature of the ceiling is rejected. Should such curvatures eventuate, their radius must be small. Particularly, the curvature of the rear ceiling area will lead to sound focusing onto the last rows of the stalls. Also of great disadvantage is the dome-like raising of the mid part of the ceiling with its large step toward the stage, in which the lighting is housed... This produces very strong delayed reflections in the middle of the stalls” (Nobis, 1994, p. 38 – translation from German by Philip Nobis).

Gabler drew a number of sections with arrows representing the reflections of the sound to explain the problems of the current scheme. Furthermore, he included a number of suggestions as to how to substitute the large concave curvature with a number of smaller convex curves – see figure 15 and 16. On Gabler’s side this was an attempt to create a design tool that was ready-to-hand and thereby immediately usable to Utzon.

Achieving a tectonic Building Principle

Gabler’s attempt was successful and immediately after his letter arrived in Sydney, the drawings being produced in Utzon’s office began to show a concern for sound paths – see figure 16. This was the first time such considerations were shown in the Minor Hall drawings (Nobis, 1994, p. 40).

Utzon used the acoustician’s reflection line analysis to develop a principle for positioning each segment of the ceiling in relation to the audience and the stage. Cremer and Gabler instructed him about the geomet-



rical relationship that was desirable to give the audience strong early reflections. From these instructions Utzon was then able to use the simple geometrical principle as a design tool. Thereby the acousticians' principle was transformed from a method to passively evaluate a scheme into a design tool that actively generated an architectural scheme. The generation of the scheme was not determining the architectural scheme fully – there was still room for changes and nudging the ceiling curves - but through using the reflection lines as a design tool Utzon was able to draw the outer and inner perimeter that the segments had to be positioned between. When comparing use of this design tool to the two models from chapter 4 (see page 89) the design tool is here used to overcome the gap between the two professions – the measurement of reflection lines was an acoustical design tool that could be used directly in the architectural development of the schemes by Utzon. The model that best characterises this situation is thus the first one in figure 10.

This support from Cremer and Gabler is a crucial point in the case. Even though Cremer and Gabler's main acoustic design tool – like Jordan's – was the scale model testing, these two consultants commented on the scheme immediately without waiting for the results of scale model tests. They interfered – unlike Jordan – with the design of the auditoria and even supplied Utzon with a design tool that enabled him to work with acoustics as a principle in the shaping of the hall. They were, in effect, enabling Utzon to develop his architectural approach from an acoustic knowledge and thereby develop a new auditorium prototype.

The aim of these acousticians was different than Jordan's, who was inspired by the classic auditoria. Cremer, on the other hand, found that the field of acoustics had to support the development of new auditorium prototypes and demonstrated this with the Berliner Philharmonie. This hall has in some respects (for

instance the musician's ability to hear one another) an acoustic quality that is not as good as the classic hall types when measured in objective parameters. Never the less, it is one of the most festive auditorium prototypes due to its visual character and is extensively copied.

From this difference between Jordan and Cremer/Gabler as consultants, it can be said that it is not only the design tools available that obstructs a tectonic practice; Jordan's hesitance caused by his habitus hindered the tectonic practice more than the available design tools did. In this case, therefore, it is clear that the actors are the determining factor because Cremer and Gabler could enable the tectonic practice even though their main acoustic design tool was the same as Jordan's. The manner Cremer and Gabler enabled the tectonic practice was through a design tool that they sketched out for Utzon and he then developed himself - the convex curves could be positioned by the drawing of reflection lines and this method was suitable as a design tool in exactly this design context.

In short, Jordan's habitus and his use of only the main acoustic design tool obstructed the tectonic practice while Cremer and Gabler's habitus and how they supplemented the main acoustic design tool enabled the tectonic practice.

The stepped cloud scheme was being reworked completely within a few months. The new scheme called no. II encompassed all the changes suggested by Cremer and Gabler – see figure 24 – and clearly the instructions from Cremer and Gabler served as a ready-to-hand design tool to Utzon. "There was a fine collaboration between my office and the acoustical experts in Berlin and it was soon evident that this solution was acoustically good" (Utzon, 1965a, p. 2). Many of the intentions from the stepped cloud scheme, such as the radiation

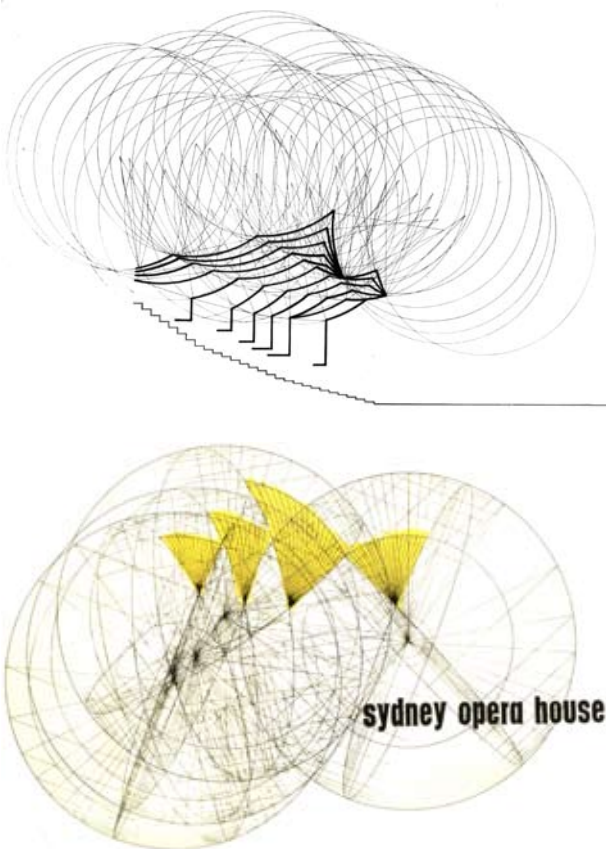


Figure 22-23: The similar drawings of the acoustical profile of the Minor Hall and the sail geometry

from a centre point and the entrance to the hall, were retained. Inspired by the newly found “spherical solution” for the sails of the Opera House that was based on the geometry of a sphere; the large concave curvature of the ceiling was inverted to smaller convex circles with differing radii. Even the drawing describing the spherical solution and the drawing by Raphael Moneo describing the acoustic profile of the Minor Hall are related in drawing style.

Niels Jordan has criticised the Minor Hall scheme because it directs too much of the sound towards the audience because of the projective ceiling and the lack of reflections from the side walls (Jordan, 2004). This is a relevant criticism of a contemporary auditorium but the field of acoustics in the sixties lacked a thorough understanding of the importance of the direction of the reflections (Barron, 2000). In the context, then, the Minor Hall must be seen as a valid example of an auditorium from the sixties.

Sophisticated standardisation

Having found a solution that worked as a tectonic Building Principle, the rest of the design development did not present any major obstacles. Utzon continued to develop the scheme in order for it to be manufactured and assembled easily. In this respect he was drawing on his experience from the development of the Opera House sails and the advice from Arup to rationalise the components by using geometrical primitives.

Within a few months scheme II was further refined and developed into scheme III. The major difference between the two was that the cylinders now had the same radii in order to simplify production. Each sector of the circles was developed as a separate boxbeam with an inner surface that was visible from the inside of the auditoria and an outer surface that was visible from the foyer space.

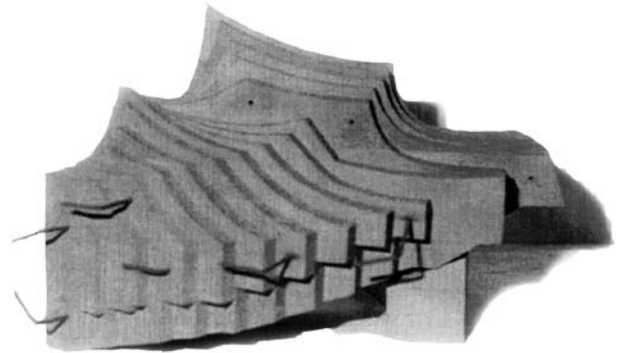


Figure 24: Model of the convex proposal

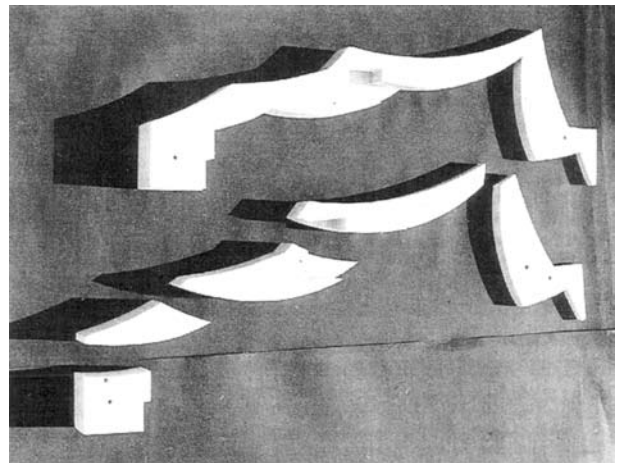


Figure 25: Model demonstrating the assembly of the ceiling segments from curved components

Manufacturing and application of finishes in a bright red inspired from China was to happen at Ralph Symond's factory so that the elements only needed to be assembled on site. By working consciously with the advanced plywood technology of Ralph Symond's factory Utzon had created what he called a "big jig-saw puzzle in space" (Utzon, 1965b, p. 83). Through these efforts, the Minor Hall became tectonic in the aspect of Component and Composition – the consideration of the components had influenced the architectural expression and was equally representation and ontology of the design. Also Utzon had showed that it was not necessary to follow the rectilinear principle of the early Modernist in order to mass-produce building components (Drew, 1999).

With the right approach to the design development from the outset, the design developed quickly and the acousticians recommended a few alterations to the geometry that developed into scheme IV. Only then was the large 1:10 scale models built. With the design almost fully developed with regards to construction, assembly and materials the model building could begin. The construction of the models took several months and was a great expense to the project; therefore it was important to make sure that it was a solid project that was tested with the method. This was even more so because only minor changes could be tested in the scale model – it would for instance not have been possible to change the ceiling from concave to convex without building a new scale model.

In this well developed stage of the design, the scale model testing was a ready-to-hand design tool because it related well to the level of detailing that the scheme had, and it can be said that the main acoustic design tool in this stage of the design enabled a tectonic practice. The scale model testing cannot be said to be a design tool that overcomes the gap between the professionals because it was a strictly acoustical design tool developed and used by the acoustician. However, at this stage of the design, where the main idea had been developed and the main design decided upon, the design tool was ready-to-hand because it enabled the final adjustments and fine-tuning of the acoustics.

Cremer and Gabler as well as Jordan tested scheme IV with model analysis; the model built in Berlin was tested between February and June 1965. The results were generally satisfying and Cremer and Gabler made only minor suggestions for changes. These suggestions were incorporated by Utzon into a new scheme, scheme V, which were drafted in the remaining part of 1965.

While entailing on the Opera Hall project as an acoustic illiterate, Utzon ended the project as an expert designer of acoustical form. In his report from 1965 Utzon remarks on the acoustical design development,

"A number of laws clearly define when disadvantages such as echoes occur, and so on, therefore it is possible to draw on paper the shape which will, in an original way, give direct sound to all the seats. This is absolutely creative work. The shape which gives a certain amphitheatre feeling, as in the Minor Hall, provides the most brilliant and clearest sound from the orchestra pit or stage – it is creative work because such a thing as "This is right" or "This is wrong" does not exist. The solution can only be found by experiment and my experiment became actually realistic only after I had learned how sound behaves. It takes a long time, and good co-operation with acoustical engineers, to understand the properties of sound. On the

other hand, it also took a long time for the acoustical engineers to understand the freedom with which my concepts allow us to work. Normally, acoustical engineers are repairing a fixed project.” (Utzon, 1965a, p. 2).

Utzon’s newfound understanding of acoustics is evident not only from the final design of the Minor Hall but equally from the design of Bagsværd Church from 1973 which he conducted without the assistance of acoustical consultants. Here he took many of the principles developed in the Minor Hall to their perfection. The convex curves of the ceiling are used to radiate the sound and they thereby reflect Utzon’s understanding of the fundamental principles of room acoustics. The result is a very good quality of room acoustics (Mortensen, 2005). The curves are also the backbone in the construction of the building because the curves add to the stiffness of the eight centimetres thin concrete plates and thereby enable them to span the 17 meters of the church room. This church room must be said to be one of the most unique and amazing spaces in Danish architecture and can perhaps be said to exemplify what Sydney Opera House missed when Utzon’s Minor Hall was not build.

WHAT MADE UTZON ABLE TO CREATE TECTONICS IN THE MINOR HALL?

While the focus here is on Utzon’s ability to create tectonics in the Building Principle approach, it is worth pausing for a minute on the two other tectonic approaches. In the tectonic approach Materiality and Technique, Utzon’s collaboration with Symonds was crucial. Utzon did not know the material at hand well and especially not the characteristics of plywood when it was combined with lead as a composite material. The expertise that Symonds could offer in the field enabled Utzon to

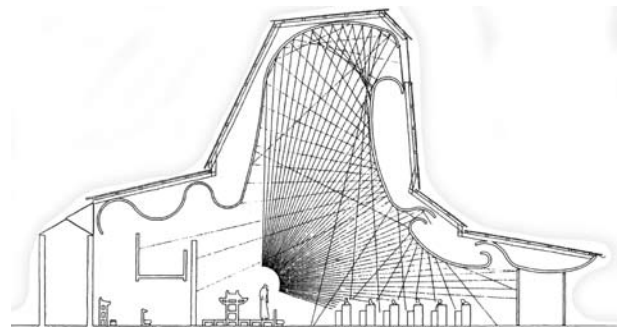


Figure 26: Bagsværd Church

take advantage of this new material in the architectural expression of Minor Hall. Utzon's method of creating tectonic architecture in the Materiality and Technique approach relied on getting to know the material intimately through building full-scale mock-up models - a method that Utzon had also used with the tile producers Höganäs in connection to the development of the prefabrication system of the sail-elements. In this approach, Utzon was close to the classic master builder role that could test his ideas on site and with actual materials – in this case the site was just the production plant instead of the building site. The method was, however, for the same reasons problematic in the industrial age. The competitive tendering system was introduced in order to economise building, and Utzon's experimentation with Höganäs and Symonds was seen as anti-competitive because the firms that Utzon had collaborated with would have an advantage in the tendering process. Even though Utzon argued that the development of a production method through collaboration with the producer gave the most rational and economic building project, the Australian building industry was not satisfied. Regardless of this discussion - the conclusion is that it was only through the collaboration with Symonds that Utzon could develop a tectonic solution in the approach Materiality and Technique.

In the approach of Component and Compositions, Utzon was already quite experienced when he began developing his scheme for the Minor Hall. His collaboration with Ove Arup and partners were significant in developing his ideas in this direction but already before Utzon and Arup met in 1957 Utzon had a profound interest in this aspect as he demonstrates in this essay on tendencies in contemporary architecture from 1947, where he described his principle of Additive Architecture (Utzon and Faber, 1947). Utzon's knowledge of boatbuilding, his ability to work with three-dimensional objects and his system of keeping track of the geometry as points in three dimensional coordinate systems rather than only drawing plans and sections, were important in this respect. In this tectonic approach the habitus of Utzon as well as his experience from the other parts of the Opera House project were what enabled him to create tectonics in the Minor Hall.

Building Principle tectonics - enabled by actors with the right design tools

While the two mentioned tectonic approaches relied on Utzon being able to work as a modern master builder with access to materials in full scale, developing the production methods and having full control of the geometry, the last tectonic approach was more dependent on Utzon being able to understand the scientific knowledge of a field and be able to transform it into design information.

The last tectonic approach, Building Principle, is the focus here and also the most interesting in connection to the Minor Hall design. While it is clear that this was the most problematic part for Utzon, it is also the most extraordinary in the sense of Utzon's development from being an acoustic inexperienced architect who sought guidance from architectural examples rather than scientific understanding to being an architect who could design with acoustics as a tectonic Building Principle.

What was it actually that made Utzon able to create a tectonic Building Principle from the acoustic requirements? It is immediately clear that the collaboration with his acoustical consultants was immensely important but it is also evident that the design tools – whether a main tool or more self-invented tools - available

also played a significant role in enabling Utzon's tectonic practice.

Jordan and the inspiration from classic auditoria
As it was mentioned in the design development, Jordan did not support the design development in the first stages and the question why Jordan did not comment on the shape of the ceiling in the stepped cloud scheme seems to be an excellent starting point for a discussion of what enables and what obstructs a tectonic practice.

Jordan's hesitancy can, as argued in the design description, not be explained by the design tools alone. When compared to Cremer and Gabler it is evident that his hesitancy must be explained by Jordan himself also. This is supported by Jordan's understanding of acoustics as a field relying on the traditional technology of the classic auditoria. As Zhang (2005) has described, the field of architectural acoustics has developed from relying on myth in ancient times, over relying on copying precedents of successful auditoria in the seventeenth and eighteenth century, to becoming a scientifically grounded field during the nineteenth century. Jordan's approach was a combination of being inspired by the classic auditoria that were known to work acoustically and of being able to evaluate new architectural approaches through a scientific approach.

The reliance on the classic auditoria by Jordan was seen in the Red Book proposal while his scientific approach was evident in his ability to evaluate any given design that Utzon would develop. In order to be able to give scientific advice, Jordan relied on the slow, detailed and expensive scale model testing. When the large scale model is built, smaller changes can be made to the design – for instance the introduction of reflectors – and the effect of these changes can be measured, thereby improving



Figure 27: Vilhelm Lassen Jordan sitting in a large scale model ready for acoustic testing.

the acoustic quality through sub-optimisation. This method did not support Utzon in his quest to develop the architectural expression to inherently take the acoustic requirements into consideration instead it would have acoustically corrected a design that was developed without much consideration of these requirements. In fact, this method of Jordan's might have been what prompted Utzon to comment "Normally, acoustical engineers are repairing a fixed project." (Utzon, 1965a, p. 2). Jordan could probably have made the stepped cloud scheme work with reflectors attached all over the hall but it would not have resulted in a tectonic scheme because it would signify a separation between architectural and technical concerns instead of a solution where the two were one and the same thing.

To be fair, then, it cannot be concluded that Jordan could not have supported a tectonic practice based on traditional prototypes. If Utzon had worked with the known prototypes of auditoria, Jordan would have been able to supply his expertise and support. Only because Utzon insisted on a tectonic approach that developed new prototypes, Jordan's advice was inadequate.

The scientific approach of Jordan is, however, understandable for his time. He was taught in the acoustic field at a time when it was struggling to be acknowledged scientifically and as Bourdieu has described (2005) a new field that attempts to constitute itself as scientifically credible is even more than the well constituted fields of science forced to play by the rules of the scientific community. This is the only way to gain scientific capital and become a credible autonomous scientific field. Acousticians at Jordan's time could therefore be expected to be very concerned with upholding scientific standards such as objectivity and basing knowledge on well documented empirical studies.

The scientific concern of Jordan obstructed the tectonic practice by awaiting a fully developed scheme and thereby not supporting an incorporation of the acoustical requirements into the architectural scheme as a Building Principle that helps shape the architectural form.

Cremer, Gabler and the creation of ready-to-hand design tool

When comparing Jordan to Cremer and Gabler as consultants, it is clear that Jordan's difficulty in enabling a tectonic practice was not only due to the design tools available. These acousticians working at the same time and with the same design tools available went about the problem in a different manner - Cremer and Gabler invented a design tool that was ready-to-hand to Utzon because it was envisioned as a direct response to the actual design. In this case the ability to create tectonics was not conditioned by the present design tools, rather the design tools were conditioned by the actors. Instead of the design tools enabling the actors, it was the actors inventing the design tools necessary. In the models from chapter 4 of the relationship between actors and design tools, the design tool that Cremer and Gabler invented created a situation that can best be described by figure 10, where the design tool enables an overcoming of the gap between the professions.

Lothar Cremer was one of the greatest acousticians of the twentieth century and was a driving force in developing acoustics as an autonomous scientific field. While Jordan was one of the – if not the – best Danish acousticians of his time, Cremer was never the less in a different league. As a scientist, Cremer



Figure 28: Berliner Philharmonie interior where the principle is to position the audience around the orchestra

certainly was not subordinate to Jordan. His professional habitus, however, was different.

When working with Utzon, Cremer was about to conclude a very successful collaboration with Hans Scharoun on the Berlin Philharmonie (1956–63). Scharoun had, like Utzon, no interest in the classic auditoria of Europe but wanted the auditorium to reflect what he understood as the natural way of assembling around a performance – in a circle all the way around the orchestra. From an acoustic point of view, this was very difficult to solve for a number of reasons but Cremer agreed to give it a try on the condition that he was given free hands to influence the design,

“Cremer struck a bargain with Scharoun: if they were to pursue the difficult and risky idea of music in the round, Cremer must be allowed freedom to make the forms work acoustically. Scharoun agreed and a fruitful collaboration ensued...” (Jones and Kang, 2003, p. 82).

Today a debate is still persisting between acousticians who criticise the acoustic quality of the Berliner Philharmonie due to the measurements of the objective acoustic parameters, and the ones arguing that it is an interesting hall with a much better holistic experience between sound and vision thereby offering something else than what can be measured as objective acoustic parameters. Cremer, however, argued that despite the obvious benefits of the guaranteed good sound quality when using historical precedents (the classic auditoria shapes) this approach would be the end of architecture and prevent innovations (Cremer and Muller, 1982). Therefore they were supportive of Utzon's quest to use new technology and not begin from the classic auditoria. Unlike Jordan, Cremer had no hesitations in interfering with the architectural form. As mentioned, his partner Werner Gabler, an architect specialised in acoustics probably had his say in this ability of Cremer to be able to give design suggestions.

When Gabler and Cremer entered the project they therefore brought with them a different practice than Jordan's that could enable a tectonic practice. One could say that while Jordan's actions primarily was intended to increase his scientific capital from other acousticians and scientists by providing bullet-proof, objective advice to the architect, Cremer and Gabler took advantage of their double-role as scientists and consultants by pushing the architect in the right direction. Cremer did not only issue comments on the stepped cloud scheme, Utzon received diagrams from Gabler that explained the principles behind their comments. This probably reflected on their whole practice; Cremer's assistant Joachim Nutsch, who was working with Utzon in Sydney, was known to be a talented sketcher able to demonstrate in drawing what he suggested to be altered.

Utzon's willingness to adopt the acoustic principles into his design was naturally a great part of the success of the collaboration but with the diagrams Cremer and Gabler gave Utzon a design tool that crossed the boundary of acoustics into architecture and could be used as a ready-to-hand design tool – a design tool that was so well-suited to the task at hand that one stops to think of it as a design tool and allows oneself to direct all attention to solving the task.

When Gabler and Cremer were introduced to the project it was thus not primarily technical talent that was added to the project, rather it was another professional habitus closer to that of architecture and sympathetic of what was needed to enable a new architectural approach to develop from a acoustic requirements. The strength of Gabler and Cremer's advice on changing the concave ceiling to convex curves was that it was able to support the design process in a much earlier stage than the scale model testing. Therefore it was suitable to enable a tectonic practice from the very outset of the design process.

The introduction of the new consultants enabled a tectonic practice. Not only did they understand the intimate relationship between the architecture and the acoustics that Utzon wanted to achieve, they were also able to support the relationship with a ready-to-hand design tool able to support the early design development. Both the actors and their use of design tools were thus significant in enabling a tectonic practice.

Utzon and the tectonic intentions

While the difference between the engineers' actions, professional habitus and use of design tools is quite obvious, the role of the architect is no less significant. As the analysis of the engineers show, they cannot be explained solely as being engineers and likewise Jørn Utzon's actions cannot be explained solely from the fact that he was trained as an architect. This would be to overlook the great variations between architects that are no less than among engineers. An upbringing close to harbours and shipyards has often been mentioned as one of Jørn Utzon's great sources of inspiration and this is also what Jan Utzon, his son, chooses to focus on in his description of his father,

"There my father saw how the ships were drawn, how they were executed in the workshops and how the human being with his hands can shape steel, erect it and assemble the pieces so that in the end it becomes a ship able to carry cargo or passengers. That upbringing has my father mentioned as very important to his activity as an architect because it made him confident in that what is sensible drawn can also be manufactured." (Utzon, 1988, author's translation).

The connection to the ship industry is something that Utzon explains as something that has influenced him to appreciate a holistic solution, "Everything that you have on a boat has the right dimension and the right material so that you have an extraordinary unity..." (Clouds: Jørn Utzon, 1994, author's translation). The upbringing near the shipyard as such gave Utzon an interest in tectonics in the sense that he understood how the materials had each their strength and inherent expression and how this could become a part of a holistic expression.

Utzon's habitus from his upbringing was developed into a professional habitus by his teachers at the school of architecture in Copenhagen. One of these, Steen Eiler Rasmussen, wrote "Experiencing Architecture" (1957) wherein he advocated a more tactile and experience-based architecture than what was offered by the Modernism at that time.

"When in a room one exclaims: "How rigid and cold it is", it is not necessarily cold with regards to temperature. It might be that shapes and materials are experienced unsympathetic – i.e. something that one feels. It might be that the colours are cold – i.e. something that one sees. Or it might be that the acoustics is hard so that especially the high tones resonate – i.e. something that one hears. If the same room is given warm colours or equipped with carpets and curtains so that the acoustics is less hard, one will – even though the temperature is exactly the same as before – feel that it is nicely warm." (Eiler Rasmussen, 1957, p. 227, author's translation).

This was a great inspiration to the young Utzon and the continuing correspondence between him and Eiler Rasmussen testifies to their mutual understanding of architecture. Also the encounter with Alvar Aalto, whose office he worked in shortly, further developed Utzon's humanistic approach to architecture.

Utzon as an architect was not just any architect and this is evident in the development of the Minor Hall. While the restriction of the Opera House sails was one of the pragmatic conditions that forced Utzon to

break away from the classic shoebox shaped auditorium – the shoebox simply would not fit under the shape of the sails that was already being built – Utzon was himself keen to create a new type of auditorium. In keeping with Eiler Rasmussen's belief in an experience based architecture, Utzon wanted a connection between the visible and the audible. In connection to structural solutions Utzon would say, "The structure is the architecture." (Clouds: Jørn Utzon, 1994, author's translation) and this credo, Utzon would use again in the Minor Hall – here the acoustic requirements was the architecture. In other words, Utzon wanted to portray the acoustic function of the auditorium and create an auditorium that was tectonic in the Building Principle approach. The new architectural expression should not only be based on visual concerns but on the newest understanding of acoustics. By creating an architectural solution that was a direct reflection of how the sound should be dispersed to the audience, Utzon wanted to create an architecture that was particular to his time – a project that many Modern Architects had before and after Utzon.

Utzon's ability to realise this architectural project was perhaps better than most others due to his upbringing close to the shipyard and his ability to take in other disciplines. To be able to create the experience Utzon wanted in the Minor Hall, he needed to understand and become able to work with the field of acoustics. Ove Arup, his structural engineer, at one time remarked that Utzon was incredible in his ability to absorb new areas of technical knowledge "He... has a remarkable grasp of or ability to quickly understand the essence of other technical disciplines as they impinge on his architectural conception" (Drew, 1999).

This ability of Utzon to be able to adopt other technical fields into his schemes, were crucial to his ability to create tectonics. While Utzon may have lacked experience in managing the political aspects of a large project, as Murray (2003) and Flyvbjerg (2005) have suggested, he was the determining factor in creating tectonics. The habitus of Utzon led him to insist on getting advice that could enable him to create tectonic architecture with a new architectural approach and a new technology substance instead of beginning from the traditional technology of the classic auditoria.

CONCLUSION - ACTORS SUPPORTING THE EARLY DESIGN STAGES ENABLES THE TECTONIC PRACTICE

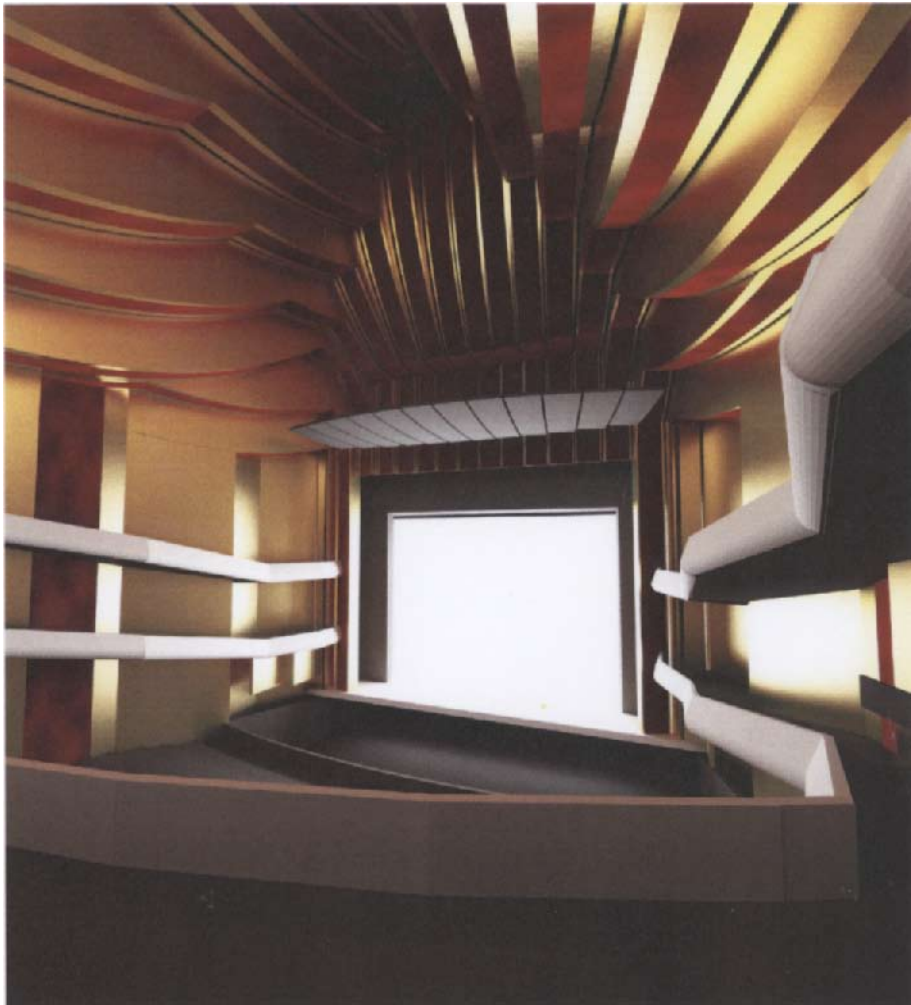
The professional habitus of the engineers advising Utzon as well as their use of design tools were absolutely crucial to Utzon's ability to create tectonic architecture, which was analysed in connection to Jordan, Gabler and Cremer as actors. Nevertheless, these factors depended on Utzon's own professional habitus and insistence on a tectonic solution. As such, none of the subsequent factors – the dismissal of Jordan's proposal, the employment of additional advisers, Gabler and Cremer's use of ready-to-hand design tools – had been set in motion if not Utzon had insisted on it. In the sixties, Utzon still acted as a sort of modern master builder, who decided how the project was to be developed; therefore his attitude towards creating tectonics was the single most important element that enabled the creation of tectonics. The modern aspect of his role was, however, that he did not work only from his own understanding of acoustics but worked closely with his consultants – at least with the German ones.

Jørn Utzon attempted to develop the auditorium as a new architectural expression using a new technology.

His first acoustician, Jordan, was inspired by the classic auditoria and he found it difficult to support Utzon's approach. Jordan was a skilled acoustician who had pioneered one of the most advanced acoustic tools at the time, the scale model testing, but this design tool and Jordan's professional habitus could not support Utzon in his tectonic practice. Utzon's second set of acousticians supplemented the scale model testing by small design tool that could support Utzon in the early stages of his design. Thereby they enabled a tectonic practice where the architectural expression was developed from a new acoustic technology. The design tools from Cremer and Gabler had the ability to be positioned between the professions and then be described by the model in figure 10 (see page 89) as well as it was ready-to-hand in the early design stages. In effect Utzon could not have created a tectonic solution to the Minor Hall if only the scale model had been available as a design tool and the second set of acousticians as well as their crude design tools enabled a tectonic practice by overcoming the gap between the professions.

The discrepancy between the consultants, then, suggests that a tectonic practice depends more on the professional habitus of the actors than it does on the design tools available in the design process – these available design tools can always be supplemented - and that the design tools that are able to support the first stages of the design are crucial to enable a tectonic practice with the development of new Building Principles.

It can be concluded, then, that the habitus of the actors is the first and foremost important factor to enable a tectonic practice. Even with the same design tools available, it differed whether it was possible for the actors to enable a tectonic practice. The manner that the actors support the tectonic practice is, however, with design tools. The tectonic practice is therefore dependent on a closely intertwined relationship between the right actors and the right design tools that will enable an incorporation of technical concerns early in the process.



THE OPERA THEATRE CASE

In the pre-digital age it was primarily the instructions from the consultants that made Utzon able to create tectonics while the design tools were slow and troublesome to use. Could the introduction of new and quicker design tools in the digital age signify that design tools play a greater role in the creation of tectonics? This is what the second part of the case will shed light upon by again focusing equally on the actors and the design tools in the design process.

The conditions when dealing with an ongoing project as a case is that the majority of the information about it needs to be found through interviews. In this case the primary sources are Joseph Skrynzki, Chairman of the Sydney Opera House Trust from 1996-2004, Norman Gillespie, CEO of the Sydney Opera House; Greg McTaggart, Director of the Building Development under The Sydney Opera House Trust; Richard Johnson, Opera House architect and partner in the architectural firm Johnson, Pilton, Walker; Matt Morel, project architect and employee at Johnson, Pilton, Walker; Jan Utzon, son and partner of Jørn Utzon; Andrew Nicol, director Arup Acoustics Australasia; Niels Jordan, acoustical consultant on the Opera House from 1966-1973. These sources are chosen because they have all been directly involved – politically or in terms of design – with the design of the Opera Theatre.

In addition to these actors, newspaper articles, conservation plans for the Opera House (Kerr, 1993; Kerr, 2003), annual reports from the Sydney Opera House Trust (1998, 1999, 2001, 2002) and the few printed sources available (Peter Murray's book "The saga of the Sydney Opera House – The dramatic story of the design and construction of the icon of modern Australia" from 2004 and "The Sydney Opera House" by Floyd and Collingwood, 2000) are used. Also a few interim reports supplied by Johnson, Pilton, Walker and Arup Acoustics have been helpful to understand and reconstruct the case.

From dismissal to re-engagement of Utzon

As a prelude to the description of design development in the digital era, the background to how Utzon got re-engaged the Opera House is interesting. After Utzon left the project in 1966, a team of Australian architects Todd, Littlemore and Hall took over the project and the Opera House project changed considerably. The building programme was analysed and a great deal of the vagueness that Utzon had struggled with was sorted out. This led to major changes to the interiors yet un-built. For instance the Major Hall, which in Utzon's scheme was intended for opera and concerts, was changed to containing solely concerts and the Minor Hall, which was originally for theatre and recitals, became dedicated to opera (Fromonot, 1998).

In effect; where Utzon was asked to create two multi-purpose halls, the brief now asked for two mono-functional auditoria which was easier to solve acoustically and functionally. The change of brief can only be characterised as a sensible decision but with the consequence that the auditoria design envisioned by Utzon was no longer usable. Instead Todd, Littlemore and Hall designed two new auditoria within the existing building in collaboration with Vilhelm Lassen Jordan and his son Niels Jordan.

The new auditoria were quite different from what Utzon had designed and acoustically the changing programme resulted in a well functioning Concert Hall (previously Major Hall) but an inadequate Opera Theatre (previously Minor Hall). One could say that the change of architects reversed the quality of the halls.



Where Utzon had difficulties in solving the Major Hall (Nobis, 1994) but had an excellent scheme for the Minor Hall (Murray, 2004), the new architects created a well functioning Concert Hall (Johnson, 2005a) but an inadequate Opera Theatre (Jordan, 2004). Despite its name, the Sydney Opera House ironically enough, is not well functioning for opera.

The Opera House opened in 1973 and has since then become an icon for the Australian identity and the centre of Sydney's cultural life.

Conservation or refurbishment

Discussions of the Opera Theatre as well as the general functionality of the building have persisted since its opening and grew serious around the early nineties where a discussion between conservation and refurbishment took place. On one hand the head of the Opera House Trust at that time wanted to conserve the whole building on a national level (Kerr, 1993) as well as international level for the World Heritage Listing (Floyd and Collingwood, 2000). On the other hand there was growing awareness of the functional problems of the interiors and the realisation that a heritage listing would impede refurbishment of the building. Also, a rising interest in the original interiors by Utzon led some Sydney architects to suggest that the interiors designed by Hall should be replaced with Utzon's design (Murray, 2004).

In this time of discussions of both conservation and change, a new chair - Joseph Skrzynski - was in 1996 appointed to the Sydney Opera House Trust by the newly elected Labor Government. Skrzynski was on the side of the discussion that favoured improvements of the functional and aesthetic problems of the building before a heritage listing.

"So with the heritage listing it'd be set in concrete for all time that the inside was just as important even though it was wrong. So we said 'no, we have to get the inside right at least conceptually before we get a world heritage listing, otherwise it'll be frozen.'" (Skrzynski, 2005, l. 88-92).

This led Skrzynski to engage an Opera House Architect and in 1997 the Australian architect Richard Johnson was hired.

"The government did a plan that was controversial and invited architects to send in proposals to implement the plan and we went and expressed an interest in throwing away the plan - and we got the job." (Johnson, 2005, l. 91-94).

One of the reasons that Johnson (then in the firm Denton, Corker, Marshall; now in his own firm Johnson, Pilton, Walker) wanted to throw away the plan was that it did not take the original concept of the Opera House as the starting point of the refurbishments. Among Skrzynski and Johnson, the idea of re-engaging Utzon grew in order to understand how to develop the building to be functionally adequate and contemporary, "So the importance of having Utzon alive wasn't to go backwards but to go forwards" (Skrzynski, 2005, l. 149-150).

Richard Johnson went to Spain to visit Utzon and convince him to re-engage with the Trust and the Opera House. The immediate aim was to get Utzon to write down his Design Principles for the Opera House in order for the refurbishment to be able to follow these principles. It proved quite difficult to convince Jørn Utzon to re-engage with the Opera House. With the distance of forty years to the project, Utzon's attitude was that the work of the new architects was not critical to the building as a whole. Therefore he wanted the building to be left as it were (Johnson, 2005a). Only when it became clear to Utzon how the Opera House had developed to become a lively and important part of Sydney's cultural life and that the refurbishment would enhance the public's experience of the building, Johnson succeeded in convincing him to write the Design Principles and to assist in refurbishment projects of the building (Johnson, 2005a).

"It was also his observation that, more generally, the Opera House has become more complex - rather than those halls standing alone. And it seems to work better because there was an interaction, a balance because without the big halls, the big audiences, there would never be the more experimental things going on. So the question became, let's make it work." (Skrzynski, 2005, l. 487-493).

The reactions towards Utzon's re-engagement were not just positive (Murray, 2003) but it is world news. The Opera House Trust described on their web page the role Utzon was going to play in the project,

"In 1999, original architect Jørn Utzon was re-engaged to develop a set of Design Principles to act as a guide for all future changes to the building...Jørn Utzon has agreed to be the Director-in-Charge, Master Architect and Concept Designer for these projects. This is believed to be an unprecedented situation - to have the architect of one of the world's most iconic buildings back working on his creation more than 30 years after he was last involved." (Building Program at Sydney Opera House, 2004).

This re-engagement was one of the most important factors in the public opinion and especially the opinion among Sydney architects to accept changes to the Opera House.

The Opera Theatre – two out of six refurbishment projects

The first project that Utzon was asked to do was to prepare a document that could describe the principles of the building for future generations. The Design Principles became a turning point for the general opinion on the building because Utzon through it clearly rejected the thought of rebuilding the Opera House from his original plans as many Sydney architects had argued for.

"Recently there has been some talk about rebuilding and re-modelling the entire Sydney Opera House according to the plans I made then, back in the mid 1960s. I really don't think it is a viable solution to remodel the whole building according to the old plans. The Sydney Opera House has been built and it has been used in a certain way which satisfies the users and has satisfied the people of Sydney and a lot of people from abroad for many years, so it would not be correct to go back to the thoughts and ideas that were new in the early 1960's which were based on a different programme for the building." (Utzon, 2002).

Apart from writing the Design Principles, Utzon was asked to assess the Strategic Building Plan – a long



Figure 2-3: The first of the six refurbishment projects was to turn the forecourt of the Opera House into a sixth venue. The second was to refurbish a small room called the Reception Hall into the Utzon Room, left figure. The third project was to create a loggia as an entrance to a foyer in the base of the Opera House and an entrance through a loggia, right figure. The fourth project is the acoustic improvement of the Concert Hall (the former Major Hall).

wish list of refurbishment projects from the Sydney Opera House executive committee (McTaggart, 2005). One of the projects chosen as very important from this list was the refurbishment of the Opera Theatre.

THE OPERA THEATRE – UNDERSTANDING THE EXTENT OF THE PROJECT

The two remaining projects were both concerned with the Opera Theatre. The refurbishment project on this auditorium was initially split into two projects; a new colour scheme and an enlargement of the pit. A new colour scheme by Utzon was intended to improve the appearance of the current black hall. The hall that was designed by Todd, Hall and Littlemore was painted black as many other Opera Theatres from this time to not distract attention from the stage. These black halls have, however, been criticised for not supporting the performance by creating a festive mood among the audience and the Opera House Trust therefore wanted to go back to some of the ideas that Utzon had concerning colours in the halls.

The other project, the enlargement of the pit, was motivated by the poor working conditions for the musicians. This had been a problem since the day the auditorium was completed, “they want a larger orchestra pit and that has been examined since we left Sydney in 1973...” (Jordan, 2004, l. 624-625). The main part of the orchestra pit is covered by the stage and during a performance the sound has difficulties in escaping from the pit thereby creating very loud conditions for the players in the pit. This has created problems with hearing damage among the musicians (Skrzynski, 2005).

The black hall and the small pit are both conditions that originate from the change of functions in the



Figure 4: The current Opera Theatre designed by Peter Hall

mid-sixties. The Minor Hall that Utzon envisioned was a hall for theatre, recitals and small-scale opera – performances that do not need the support of a full orchestra. Furthermore, these performances focus on the spoken word and the volume needed for acoustical purposes is therefore smaller. However, when the revision of the programme changed the room into an Opera Theatre, these premises changed. For large operas a full orchestra and a large volume is needed. The space that was left under the sails were intended for a much smaller volume and the design was therefore difficult,

“...they changed the brief to just put symphonies in the big hall and operas into the smaller hall, so it is really shoehorned in there. It is a very compromised design.” (McTaggart, 2005, l. 38-40).

The geometry of the hall is therefore as close to the sails as possible.

In 1998 the engineering firm Arup who worked on the structural design with Utzon in the fifties was also re-engaged to the project. Since the fifties Arup's has proliferated and now involves various disciplines in engineering – room acoustics being one of them and Arup Acoustics were selected among three international firms to carry out the analyses of the Opera Theatre (Nicol, 2005a). They began work by investigating how it would be possible to open the orchestra pit. This proved difficult structurally because the pit was positioned adjacent to a large tie-beam holding together the covering sails. Therefore the first part of the project was to figure out whether it would be feasible to redirect the structure. In 1998 Arup Structure concluded that it was expensive but possible to move the tie-beam.

With an initial plan for a redirection of the beam, Arup Acoustics carried out a benchmarking test of the acoustics in the Opera Theatre as a whole. Not surprisingly, the geometric benchmarking showed that the size of the orchestra pit was far from meeting international standards (Arup Acoustics, 2003). As more of a surprise, the acoustic benchmarking (carried out with computer simulations of the acoustics) showed that only in the ability to hear the singer's voice, the Opera Theatre measured up to any contemporary performance spaces. In addition, the quality of the acoustics would not improve significantly for the audience by increasing the orchestral pit.

From this disheartening result the conclusion was drawn that the acoustic problems of the auditorium was far from limited to the size of the orchestra pit. Consequently a discussion began whether it would be wise to attempt to solve the problems of the auditorium through two separate projects or whether it should rather be approached as a complete refurbishment project;

“...the bit of paint on the walls and the bigger pit didn't really stack up as a really solid business case to spend 40-50 million dollars and all you get is a coat of paint and a bigger pit, so we've then been looking at the bigger picture...” (McTaggart, 2005, l. 367-371).

The changes necessary to render the Opera Theatre a well functioning acoustical space were, therefore, not only to create a larger pit and apply a new colour scheme; a new design proposal for the auditoria was necessary. There was, according to Johnson never written an actual brief but the requirements from the

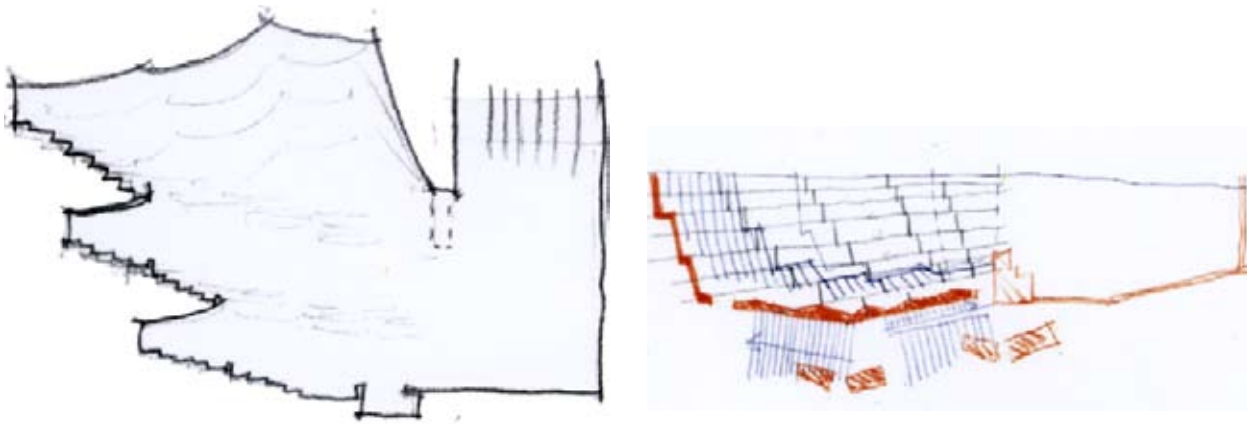


Figure 5-8: The first sketch by Jan Utzon (from January 28, 2004) and the same sketch modelled in TriForma

Opera House Trust was clear,

"In terms of the auditorium itself, there isn't a written brief. There is a requirement for 16.. in the order of 1600-1650 seats. There is a requirement for a state-of-the-art pit in terms of ability to change it quickly, ability to accommodate an orchestra with up to a 110 musician and reduce the size of the pit in various scales of orchestras. There is a requirement for world-class acoustics. And there is of course a requirement to change the auditorium back to be consistent with Utzon's principles." (Johnson, 2005b, l. 25-33).

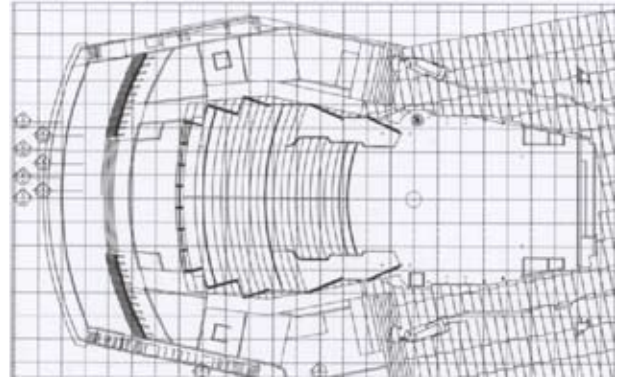
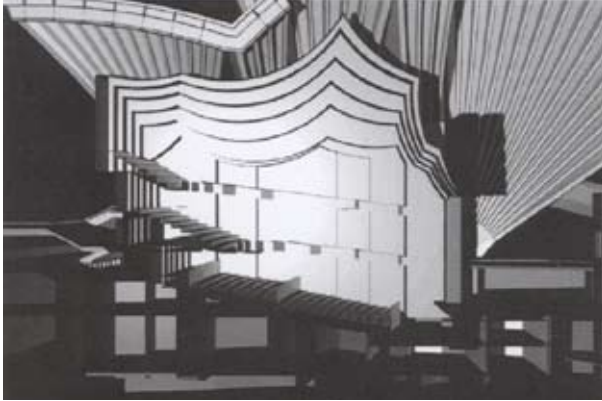
This development was, thus, the preconditions that led to a third design process on the Minor Hall now called the Opera Theatre.

Third time lucky? Stepped clouds billowing again

The design process commenced in the beginning of 2003 with the development of a strategy for increasing the volume of the Opera Theatre by lowering the floor of the auditorium. Arup Acoustics, the Utzons and Johnson, Pilton, Walker did a series of design studies, and in the end, the design team recommended increasing the volume of the auditorium by lowering it four and a half metres into the podium, "If you can't go up, you can't go sideways, then you have to go down." (Skrzynski, 2005, l. 536-537). Subsequently, the actual concept design phase, which was based on this idea of lowering the floor, was initiated in the beginning of 2004.

Arup Acoustics was engaged in the design project even before the design proper began. To inform the architects about what volume, geometry and acoustic targets the project should aim for in order to be comparable to international standards, Arup Acoustics issued a sort of guide to describe the acoustic aims,

"The first thing we had to do was that we had to set some design rules for Jan and Jorn and Richard Johnson, who was working with the two. And they're basically what we call the acoustic design rules. So they cover things from the overall volume of the auditorium to the volume per seat, the volume per seated



area which is slightly different ... All of these were rules which we wanted ... you know, they weren't absolute but they were in a range (l. 40-55). (...) it wasn't to shoehorn them into something that wasn't geometrically a workable shape." (Nicol, 2005b, l. 354-356).

Already before the first sketch had been drawn, Arup Acoustics was concerned with supplying the Utzons and Johnson with an understanding of acoustics that would be ready-to-hand in their design process.

The first sketch in the Design Studies by Johnson, Pilton, Walker (2005) is signed by Jan Utzon, January 28 2004. The concept is clearly inspired by the original interior of the Minor Hall and the fan of plywood segments with convex curves was re-introduced. The contemporary Opera Theatre, however, required an additional five hundred seats. Since the primary expansion of the hall occurs in the depth rather than in the width or length of the hall, it was natural to accommodate the additional number of spectators on tiers, thereby taking advantage of the extra height of the auditorium rather than attempting to cram them into seats on the floor of the auditorium, which was not noticeably enlarged.

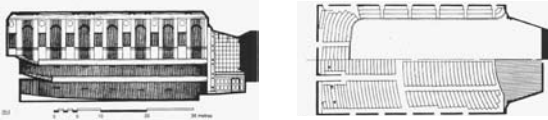
Due to the inspiration from the Minor Hall project, the first design proposal was already tectonic in many respects. The approach to materials, assembly of components and structural principle were the same as in the Minor Hall, and the tectonic quality of Materiality and Technique and Component and Composition was therefore identical to that of the Minor Hall from the outset.

In the use of acoustics as a Building Principle, however, there was a substantial amount of work to be done. While the Minor Hall inspiration already encompassed acoustic considerations, the field of acoustics had developed significantly since the design of the Minor Hall in the mid-sixties.

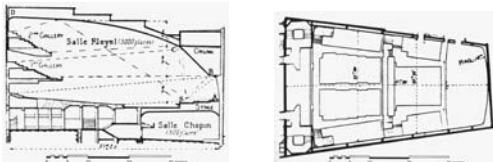
The Minor Hall design was based on the latest advances in room acoustic research from the sixties. At that time the most important acoustic parameter was the reverberation time, and the importance of the early



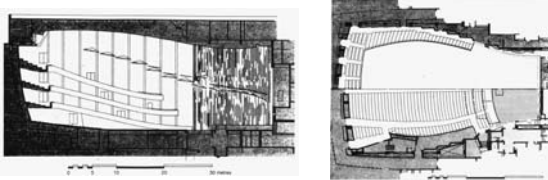
1870-80s: The rectangular (classical) concert hall (here Musikvereinssaal, Vienna)



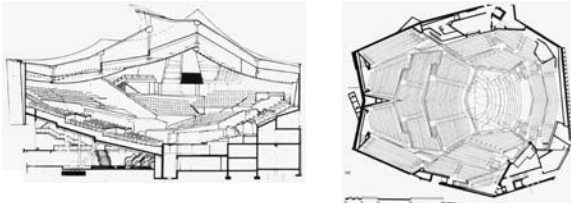
1900: The horseshoe-shaped hall (here Boston Symphony Hall)



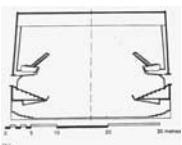
1930s: The fan-shaped plan (here Salle Pleyel, Paris)



1960s: Emphasis on early reflections (Philharmonic Hall, New York)



1963: The terraced concert hall (Philharmonie, Berlin)



1972: Significance of early lateral reflections (Christchurch Town Hall, New Zealand)



1989: Return of the parallel-sided hall (McDermott Hall)

Figure 9-21: Prototypical acoustic halls (Barron, 2000)

reflections had just been discovered. The cutting edge designs of auditoria – among them the Minor Hall – therefore emphasised the time between the direct sound and the first reflections (Barron, 2000). The prototypical auditorium of the time, of which the Minor Hall was one example, was fan-shaped and accentuated the early reflections by letting the ceiling reflect the sound directly to the audience as a projector (Barron, 2000).

Since then, however, there has been a growing awareness of the fact that the sound reflected directly to the audience does not create a lively sound in the auditorium and that the direction the audience receives the early reflections from matters a great deal to the spatial impression of the space (Barron, 2000). Architecturally, the new understanding has two consequences for the Minor Hall. Firstly, the fan-shape is outdated because it becomes important to ensure sideways reflections from the walls to the audience instead of letting all the reflections to the audience come from the ceiling. Secondly, it becomes important to position the surfaces of the auditorium so that the sound bounces between the surfaces a number of times instead of projecting all the sound towards the audience where it is absorbed (Essert, 1997).

The acoustic knowledge that the Building Principle of the Minor Hall is conceived from is thus not contemporary. The Opera House Trust asked for a world-class acoustic quality, and after an examination of the original concept for the Minor Hall, the acousticians were therefore doubtful about the inspiration from the Minor Hall proposal and attempted to dampen the enthusiasm of the architect,

“...we were cautious and we - and Richard is aware of this – we said from the outset of that this was quite a challenge and not to underestimate what

might need to be done and not to... to keep an open mind that it is not necessarily going to be this pure ceiling." (Nicol, 2005a, l. 204-208).

The architects, however, were eager to develop the scheme with the inspiration from the Minor Hall proposal. Richard Johnson seems to understand the Building Principle of the Minor Hall as an interesting acoustical principle, which could be made to work today as well,

"What surprises me I think is that nobody has tried to build an auditorium like this. These ideas have been around for forty years! There is not a single auditorium." (Johnson, 2005a, l. 206-208).

"...what surprises me that nobody else has tried it. It is probably not astonishing if you talk to acousticians because the general acoustician will tell you that the radial geometry doesn't work, that is what Arup told us initially. (...) Or that this [ceiling curves] doesn't work, but it does work." (Johnson, 2005b, l. 344-350).

One of the wishes from the Opera House Trust was to bring the auditorium back to be consistent with Utzon's principles. It is clear from the first sketch that the inspiration from the Minor Hall was very literal – the ceiling curves and the shape of the plan was the same as in the Minor Hall. One could argue that the direct inspiration from the Minor Hall, despite the changes to the acoustic field, was a more formal approach to architecture than the tectonic one that Utzon used in the creation of the Minor Hall. Would he, at that time at least, not have begun with the changes to the acoustical requirements and have created a contemporary Building Principle from that? At the same time it is easy to understand the fascination with the original Minor Hall proposal as Richard Johnson describes it here,

"...because he [Jørn Utzon] knows about geometry and because he knows about acoustics, because he knows about dispersing the sound, because he knows about how the radial geometry would work acoustically and visually this is a strong conceptual idea, that had within it encompasses everything necessary to realise the job – to make the acoustics work, to make the lighting work, to prefabricate this to get the finishes right, to adjust it subtly during design development (...) I think that is his skill, that is his great genius and I think it is a genius that comes from profound reflection about things. A lot of people has obviously tried to design opera theatres or auditoriums and they... there are so many technical issues lighting – that needs to always be in a certain position in a certain angle through here – a certain depth of the orchestra pit, a certain angle for sight lines and certain volumes for reverberation time and blab blab blab. And you can get bombed down in a mile or kilometres of technical fact or requirements. They understand them each individually and solving them individually won't produce a great auditorium. It is finding out what is the essence of those and how do they affect you as a person and as a performer, how can I harness those things and in the end not be constrained by them, not allow them to dominate the idea. But if the idea accepts them (...) they can do whatever they need to do." (Johnson, 2005b, l. 395-421).

The Minor Hall is in many ways an excellent reference because it achieved a harmony between the technical requirements and the architectural expression. Likewise, the harmony between the auditorium and the rest of the Opera House is exceptional. In many ways, then, the Minor Hall is a logical starting point with

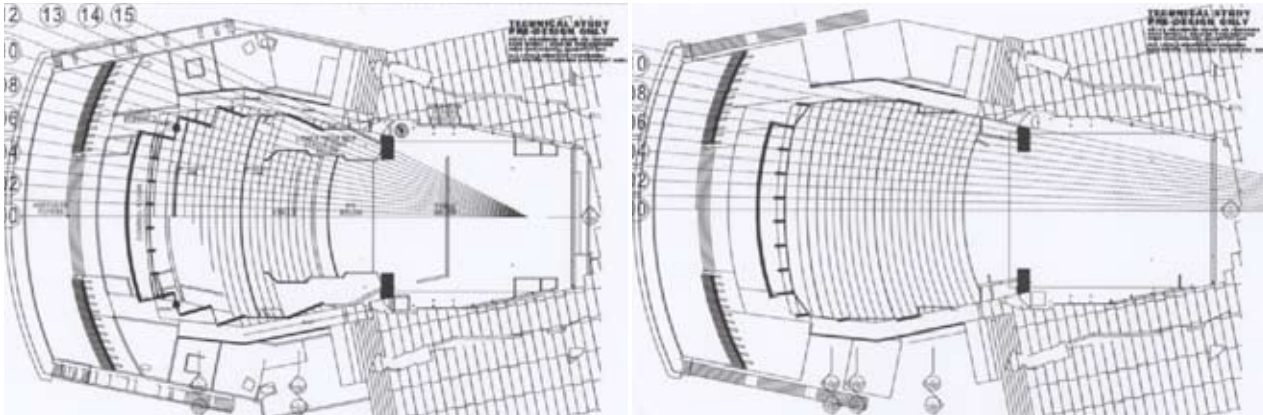


Figure 22-23: Illustration of the fan-shaped plan (February 2004) and the correction of the fan-shape by moving the centre of the radiation

the re-engagement of Jørn Utzon in mind. Only with respect to the changing acoustic basis of the project could one argue that a new Building Principle would have made sense.

Finally, the architects and the acousticians agreed to make the Minor Hall serve as their source of inspiration, and thus as the starting point for the design,

"We... we used to vacillate from saying 'ok, let's start again. If you had no constraints, what would you do?' and he [Rob Harris from Arup Acoustics, London] couldn't respond. And 'ok, let's work with this idea, why doesn't this work?'" (Richard Johnson, 2005a, l. 227-230).

The challenge in using the Minor Hall as a direct reference to the shape of the auditorium was then to update it to a contemporary understanding of world-class acoustics. As early as 1965 Utzon commented that his design was not a fixed formal solution, frozen in the perfect aesthetic shape, but was flexible to be adjusted according to requirements from technical fields such as acoustics "...[it] took a long time for the acoustical engineers to understand the freedom with which my concepts allow us to work." (Utzon, 1965a). This freedom in the proposal was what convinced Johnson that it could be updated,

"If he was convinced that it was a natural expression of the acoustics and that the environment would be better (...) that would be right..." (Johnson, 2005b, l. 385-368).

The flexibility of the concept was tested in the sixties, and in the contemporary project it became the prime concern once more.

Redefining the fan – designing with acoustics as geometry

One of the acousticians' major concerns was the fan-shape of the plan, which had the effect that no reflections from the sidewalls were directed towards the audience. Like Cremer and Gabler, Arup Acoustics did

not hesitate to interfere with the geometry of the architectural scheme. The ability to affect the architectural scheme is particularly necessary today as it is understood that the geometrical shape of the auditorium has a great impact on the acoustic quality, "...the strong acousticians that are working around the world now are the people who actually are able to design and draw rather than just to be able to talk about numbers." (Nicol, 2005c, l. 257-260). This ability of the acousticians is supported by Matt Morel from the architectural office,

"More often than not, they would demonstrate to us on our drawings or on our model what is not working so far and that'swe would then say 'ok, if we do this or do that or some other thing, would that help?' And they'd go 'no', and we'd go 'then if we'd do this or do that would that help?' And they'd say 'Yeah, that might be better'. So that's one way that it has happened and then we'd go and change our drawings and offer it to them again to comment on." (Morel, 2005, l. 259-267).

To correct the fan-shape while still maintaining the original idea of the auditorium being conceived as segments running from the back of the hall to the proscenium, a subtle change had to be made. The segments and the effect of directing attention towards the stage were important to the main idea of the hall, but it was also what created its fan-shape. Therefore, the design team came up with the idea to shift the centre of the fan-shape from the original centre of the stage to a point further behind the stage – as a result the fan-shape became less pronounced.

The modification of the scheme from a fan-shaped plan to a plan that directs a larger portion of the sound into the middle of the hall was relatively unproblematic, and already from February – a month after the initiation of the design project – the changes were incorporated into the design,

"It is interesting because Utzon has radial geometry for the walls in his original proposal and that's still there in his mind but in the drawings (...) what they are showing is actually a correction to that. It is going to be experienced as a radial geometry but the strategic point – we're actually correcting the fan to more of a rectilinear shape to redirect the sound back across the stalls and certainly in that upper cubic volume – the upper resonant volume – so that's actually quite workable." (Nicol, 2005b, l. 530).

In the corrected scheme it was thus very important to maintain the characteristics of the Minor Hall proposal.

The cunning curves of the ceiling

In contrast to the fairly simple correction of the plan, the geometry of the ceiling proved more difficult. The geometry of the ceiling in the Minor Hall was unprecedented in auditorium design, and still today no auditorium has used this idea "...it is quite different to any other opera house ceiling in the world." (Nicol, 2005a, l. 160-161). The acousticians therefore needed to examine it well in order to understand how it influenced the acoustics.

One of the first concerns with the ceiling was to raise it as close to the sails of the Opera House as possible



Figure 24: Raising the ceiling for extra volume (February 2004)



Figure 25: Polystyrene model

in order to enlarge the volume of the hall.

The architects' studies were evaluated through 1:50 polystyrene models, and the acousticians found that the raised ceiling produced some very unfortunate echoes on stage.

The use of polystyrene models in this part of the process is quite interesting: the architectural schemes were drawn in the CAD programme TriForma, the information sent to a laser-cutter that would fabricate polystyrene segments of the auditorium that could be mounted together. These half models quickly gave an impression of the void of the auditorium and could be used to evaluate the very early designs from an architectural and acoustic point of view. One specimen of the models fabricated by the architects was then handed over to the acousticians,

"...they could produce one of these models in a couple of days it was a lot quicker than getting the [digital acoustic] Odeon model done..." (Nicol, 2005b, l. 236-239).

"So we were using those and we put reflective tape on it, we used a laser and we looked to see where the sound bounces to. Very crude but very useful to get an early picture of what the geometry was doing." (Nicol, 2005a, l. 356-362).

The analysis of the use of polystyrene models, then, is one example of how the communication between the architect and acousticians was supported by the use of the computer. The use of this design tool, which is common among acousticians, ensured that Arup Acoustics could respond to schemes with a low level of detailing. As in the Minor Hall case, the ability to investigate the acoustic quality in an early stage of the design process was crucial to the incorporation of the acoustical concerns into the design, and the guidance provided by the polystyrene model analysis was very helpful to the architects in the early stage of the design – thus, this design tool became a ready-to-hand design tool in the early stages of the design.

To a large degree the analysis of the polystyrene models with reflective tape and laser projects could be compared to Jørn Utzon's use of reflection paths in the Minor Hall case. In the

case of the Opera Theatre, however, the reflective tape and laser projection was not used by the architects to develop the architectural form, but rather by the acousticians who would then conclude which changes the architectural form needed. In the early stages of this case, then, the design tool was not used by the architects to work with acoustics on their own – a use that was logical when the architects were working from the Minor Hall Building Principle.

That the architects did not work with the acoustics themselves did not mean that they did not understand what the acousticians were doing or aiming at,

“Richard [Johnson] is very understanding of our key acoustical requirements and he can speak quite animatedly about acoustics, having spend the last three years working so closely with us. It is an intuitive thing, he understands what it is that we need to do and what he needs to do.” (Nicol, 2005a, l. 481-486).

The use of the design tool by the acousticians meant, however, that an early evaluation of the schemes was possible, but the application of the acoustical principle was still in the hands of the acousticians. Based on the analysis of the schemes from the architects, the acousticians would propose changes to the geometry and to some extent function as co-designers.

Towards a shoebox shape again

The impact of Arup Acoustics’ design advice enabled by their design tools was reflected in the subsequent schemes. Through the laser investigations, the acousticians found the reflections from the ceiling to be problematic because of the risk of echoes on the stage. Therefore they asked the architects to work towards a flatter profile of the

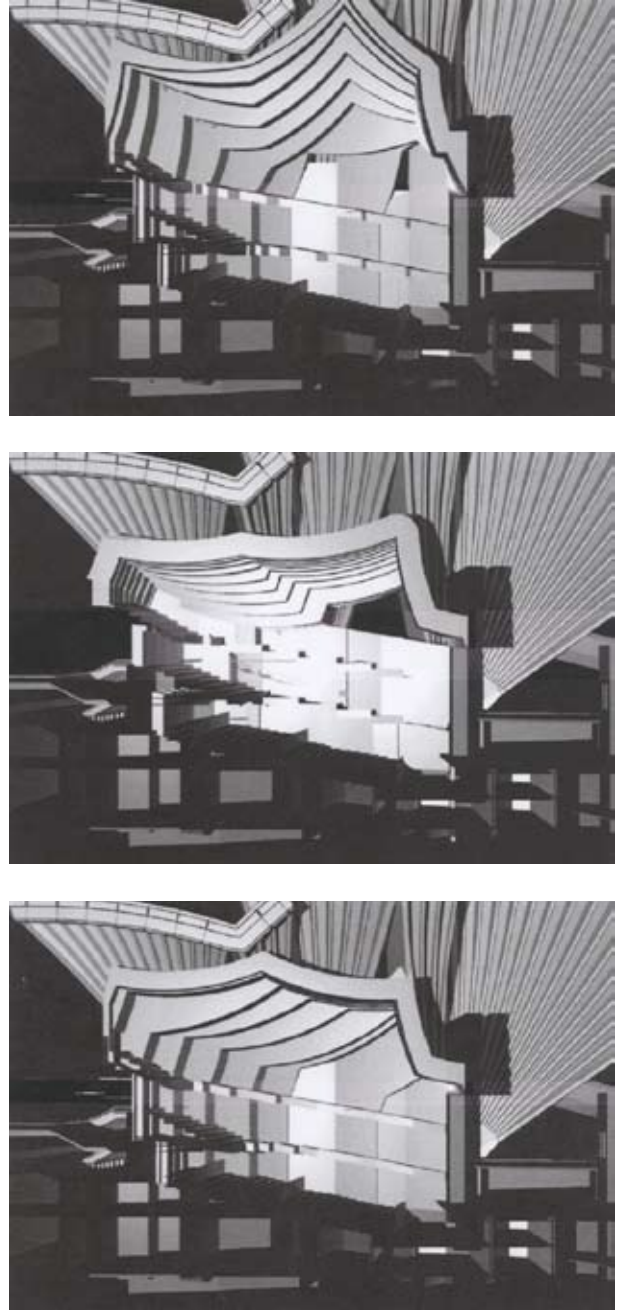


Figure 26-28: The ceiling getting flatter and flatter (February to March, 2004)

curves and incorporate an over-pit reflector in the overall shape. One way that this was attempted was to enlarge the radius of the ceiling curves to an extent where the ceiling almost became flat,

"...the ceiling was getting flatter and flatter while Arup was getting more and more concerned about the reflections from the ribs and back to the stage. It would have reached a point, clearly, where it would have been completely flat. And of course most of these were studies, knowing that the auditorium would never be built like that." (Johnson, 2005a, l. 513-518).

To the architects this seemed like a repetition of the process from the sixties where Jordan began from a shoebox-shaped auditorium. Jan Utzon comments,

"Now, we have been through the same procedures once more with new acousticians, who also began by saying that the hall should be rectangular, well-knowing that that is impossible. Since the Opera House is the way that it is, you must adapt to that form." (Utzon, 2006, l. 162-167).

Neither the high ceiling nor the shoebox-shaped hall were viable paths in the quest to update the architectural expression of Utzon's Minor Hall to an acoustically contemporary opera hall. The flat ceiling produced fewer problems with echoes on the stage, but the design was aesthetically disappointing and the full volume under the ceiling could not be included in the auditoria.

To find a new direction for the design, the design team decided to return to the original proposal once again. The drawings and models of the Minor Hall were re-visited, and the original curvature of the ceiling was reintroduced by going back to the same radius of the ceiling curves as Utzon had used in the sixties. From the schemes developed during the summer of 2004, the inspiration from the Minor Hall is clear and the emphasis on the aesthetic qualities of the ceiling curves is evident.

The re-examination of the original proposal showed the subtleness with which Utzon had solved the Minor Hall, and going back to the curved ceiling had the advantage of being able to adapt the geometry to the cavity below the sails. Also, however, it reintroduced the problem of echoes on stage, and once again the volume was not large enough.

Computer simulations solving the details of the design

To analyse these acoustic problems minutely, the acousticians used their acoustic computer simulation programme, Odeon. Nine or ten concepts were developed elaborately enough for an analysis to be carried out. The evaluation of the scheme with acoustic simulation programmes had its strength in connection with highly developed schemes.

"...while you can do certain bits of that using ray-tracing as I am doing, Odeon does it in the computer, so you can follow those traces for much longer and you can do a lot more of them so that's when Odeon comes into strength when we had something that was worth examining in that much of detail. (...) We couldn't have done this in two dimensions – at all." (Nicol, 2005b, l. 490-498).

In this process the communication between the acousticians and the architects was again assisted by the computer. The architects' digital models from TriForma could be translated into Odeon with relative ease, and within a few days the acousticians could comment on the acoustic quality of the scheme using this data. This was a clear advantage of the computer when compared to the months it took to build a physical model in the sixties.

"We guessed at how it might be done, and then they plotted our sketches into that computer technology and said, 'try to turn those surfaces,' and now we have boiled it down to a few specific surfaces that can be turned. Then we have tried to turn them slightly one way, then the other, thereby nudging the ceiling and the position and angles of the side walls to where we got the best overall sound." (Utzon, 2006, l. 316-322).

In the later stages of the design, the computer simulation was a ready-to-hand tool to assist the detailed studies of the proposal. Despite the advantage of the computer simulation programmes, however, the schemes that it can evaluate still need to be quite developed. Furthermore, the acoustic simulation programmes are so complex and specialised that it is still very much in the hands of the consultants to interpret the data and transform it to design advice for the architects.

An Utzonian Opera Theatre

The analysis of the scheme with the reintroduction of the ceiling curves showed that the problems with echoes on the stage were caused by only a part of the curves. In collaboration, the architects and acousticians found that the addition of lighting slots – another detail inspired by the Minor Hall proposal – solved these problems,

"A lot of the sections that would cause problems

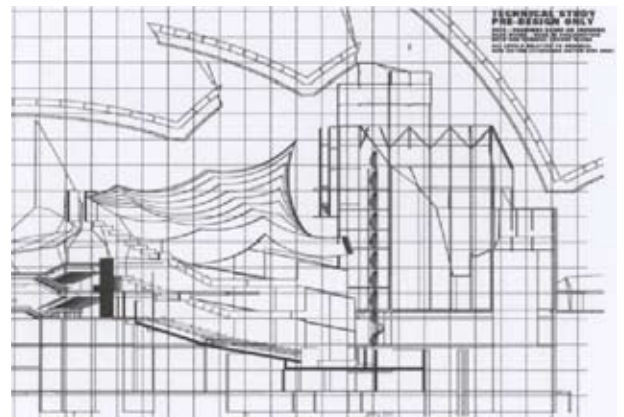
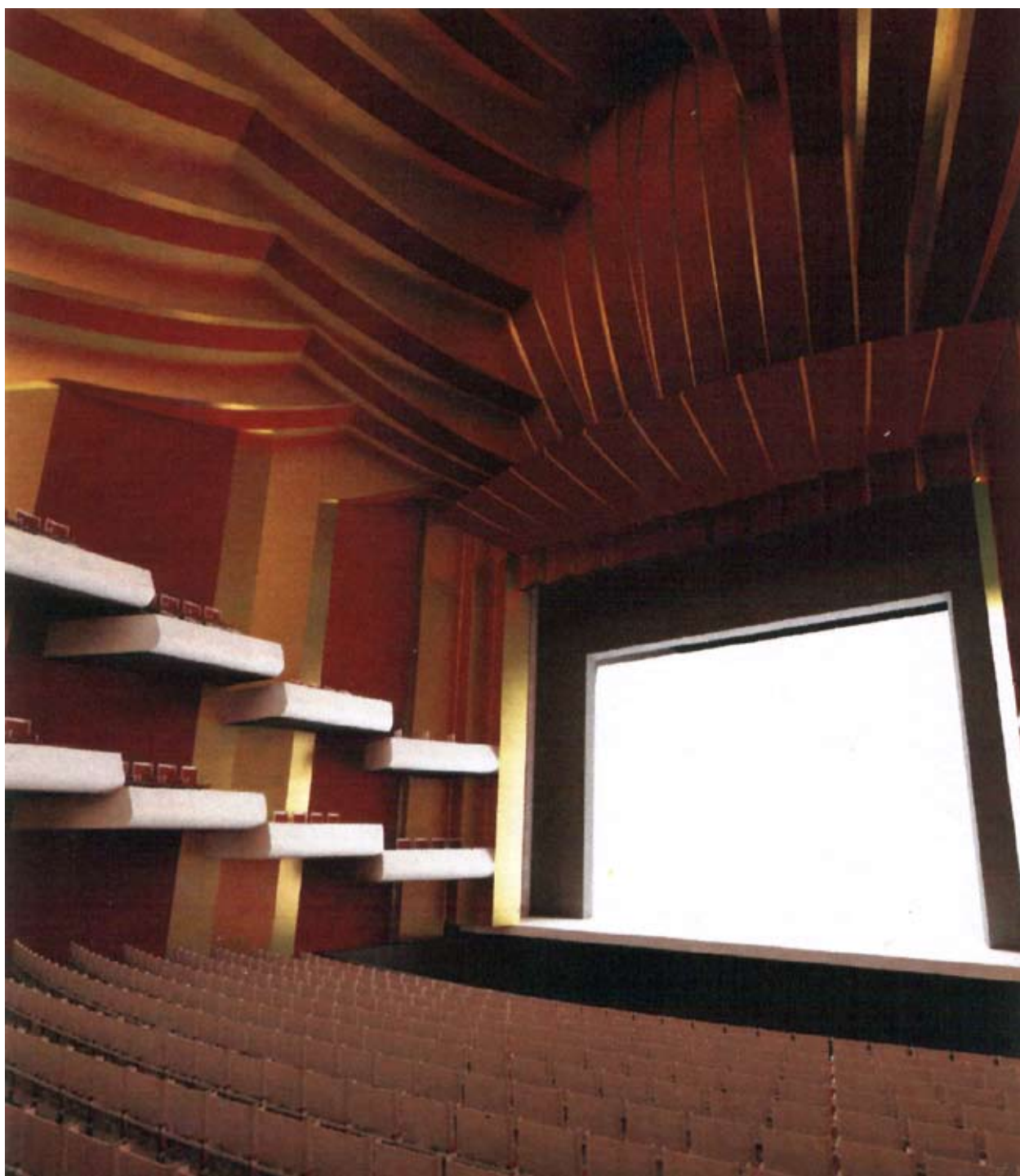


Figure 29-30: The curvature of the ceiling is reintroduced (July 2004)



are, especially in the centre part of the ceiling, actually being used as lighting slots, which is a happy way of taking away the problem.” (Morel, 2005, l. 236-239).

These lighting slots are not yet visible in the drawings or renderings of the design, and it is therefore difficult to assess their bearing on the experience of the design. To increase the volume of the hall, the height of the ceiling was raised again and the over-pit reflector became a separate element in the hall. The over-pit reflector ensured that the musicians could hear themselves and would also prevent echoes on stage. Richard Johnson describes how he was not completely convinced about the reflector and would rather have it incorporated into the form,

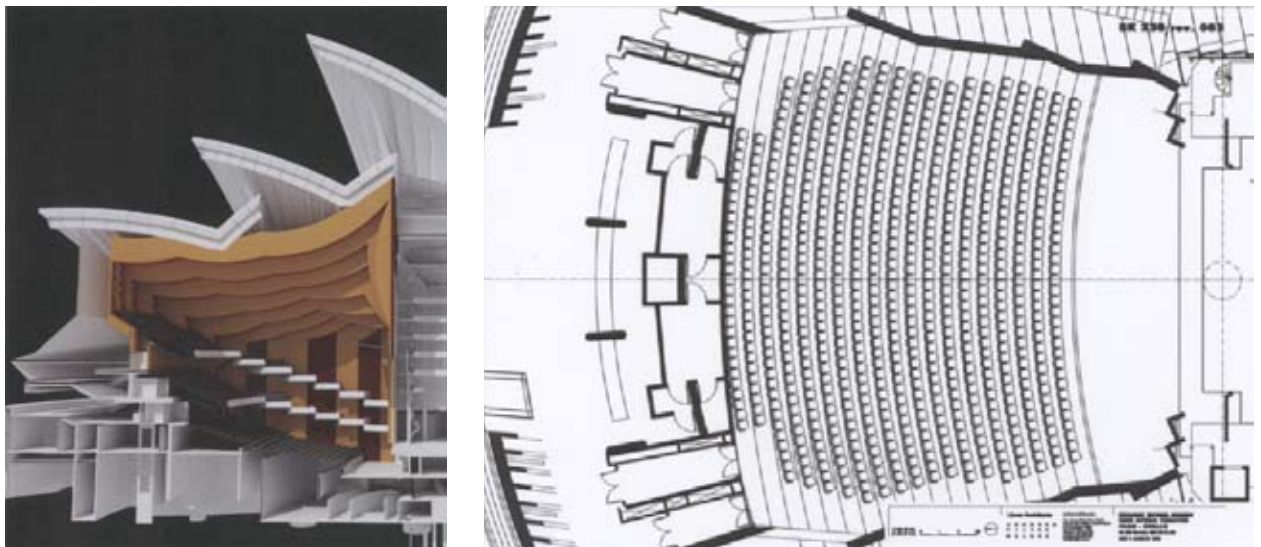
AMDS: It seems that you are not quite sure about the over-pit reflector

RJ: Oh, that’s not final yet. Because it is not in here [it is not in the final rendering of the Opera Theatre] but it is here [in the preliminary rendering seen in figure 31]. He [Jørn Utzon] doesn’t mind the idea of a reflector. Originally you can see in some of those models that we were struggling to incorporate them into the ceiling so that...

AMDS: and then you lost a lot of the volume

RJ: yes, too much volume. And this is where you needed the volume to build up the reverberence. And he accepted that and he was then quite comfortable with putting in a reflector. But he said that the reflector should take on the appearance of technical equipment – and take the shape that it needed for acoustic requirements. And probably be painted out dark and not be seen as a part of the ceiling. Arups haven’t

Figure 31-33: Final scheme of the design development (December 2004)



done yet the final fine-tuning of the model. (Johnson, 2005c, l. 755-770).

Likewise, Andrew Nicol refers to how Jørn Utzon does not mind the over-pit reflector,

"I think [Jørn] Utzon is quite open to the fact that there needs to be some sort of objects that is complimentary to his ceiling to compensate for what the shape of the ceiling might be doing." (Nicol, 2005a, l. 209-212)

Even though Richard Johnson has the assurance from Jørn Utzon that the reflector would be acceptable, from a tectonic point of view it is understandable why it was attempted to incorporate it into the overall form of the auditorium. This is the one element to which one can point as being present solely due to an acoustic concern while in the Minor Hall this division was what Utzon attempted to avoid. Where the rest of the auditorium is a harmonious solution that in one gesture unites architectural expression and acoustic requirements, the reflector is the one point where one does not find a complete tectonic marriage between the aspects.

During the autumn of 2004, the design was matured. Experiments with the number of tiers, side boxes as well as the way to reach these seats were carried out. Also, the precise ceiling profile and a refinement of the colour scheme that Utzon had intended for the hall in the sixties, was developed further.

In one year's design development, the Opera Theatre had evolved from being a tectonic design based on an out-dated understanding of acoustics to a contemporary re-interpretation of Utzon's Minor Hall scheme from the sixties. The over-pit reflector and the elimination of the problem with on stage echoes through the lighting slots reflect a more relaxed attitude towards the architecture as a reflection of the acoustic requirements. This less dogmatic attitude towards the relationship between the synthesis of the acoustics and the architectural expression is, in the case of the Opera Theatre, necessary due to the restrictions on the geometry of the auditorium imposed by the sails. Despite the need for an over-pit reflector to solve the acoustic requirements, the scheme must be characterised as tectonic in all three approaches concerned with materiality, assembly and technical principles. The design process reflects a continuous concern with synthesising the technical and symbolic aspects of the architectural scheme. This is evident, for instance from the close collaboration between the architects and the acousticians from the outset of the project.

The manner that tectonics is practiced in this case, however, is quite different from the manner Utzon worked in the sixties. There is no indication of the architects attempting to work in the manner that Utzon did in the sixties, developing a new Building Principle that would take into consideration the new acoustic requirements. Instead, the design process reflects an understandable, but also problematic, respect towards the original Minor Hall Building Principle that is applied as an architectural expression to the Opera Theatre. The original idea that beautifully reflects the acoustic understanding of its time is then subjected to an update with regards to the new knowledge of acoustics. The acoustic requirements in the brief (as described by Johnson, 2005b) leave no doubt that the issue of making the objective acoustic parameters meet international standards was a key concern.

On one side, then, there is the architectural expression that has already been decided upon, and on the other hand there is a set of high acoustic expectations. On top of this, there is a demand for a number of seats in order to finance the project; a number of seats that in turn calls for a large volume per seat and pushes the volume of the hall to its limit below the sails. In this context, then, it is no wonder that elements like the over-pit reflector are needed. The refurbishment project has placed much emphasis on reworking the auditoria from Jørn Utzon's design principles, but where Jørn Utzon would not have accepted a gap between the acoustic requirements and the architectural expression in the Minor Hall, the architectural team in the Opera Theatre needs to do so.

Heritage listing open to future changes

In early 2005, the design was developed enough for the client to be satisfied that it could be realised, "I am very satisfied that the designs are complete to a very high degree and that the costings are robust and that everything is 'buildable'" (Gillespie, 2005, l. 12-14).

The Design Principles (2002) and the refurbishment projects were incorporated into the conservation plan. Thereby the Opera Theatre and other refurbishment projects could be carried out even if the building was heritage listed. Soon after (July 12 2005) the Minister for the Environment and Heritage, Senator Ian Campbell, announced that the Sydney Opera House had been listed on the National Heritage List,

"The iconic Sydney Opera House, the building that more than any other signifies Australia to the world, has been officially recognised for its outstanding heritage value and included on the National Heritage List." (National Heritage Listing for Sydney Opera House (2005).

The concept design phase was finished in February 2005 and the project currently awaits further funding. The design team and the Sydney Opera House Trust remain confident that the refurbishment will happen eventually,

"...it'll happen some day. The most important thing is to know what to do. The momentum is there. If the solution is correct, not only giving Utzon an opportunity to do a major component of the interior but in the process solving all of the functional and operational problems that exists. It will happen, it inevitably has to happen." (Johnson, 2005a, l. 357-363).

BUILDING PRINCIPLE TECTONICS – ENABLED BY ACTORS WITH THE RIGHT DESIGN TOOLS

When understanding this case as a tectonic practice, it is important to understand why it was different from the Minor Hall case as this discrepancy permeates the whole case from the collaboration between the actors and their use of design tools. Using the concepts of the relation between technology and architectural expression, it is clear that the Minor Hall case was an example where both the technology used (the understanding of acoustics) and the architectural approach were new. Utzon was inspired by the acoustic requirements and used them to develop his Building Principle with the ceiling curves fanning out from the

stage. In this process the collaboration between the actors had to be close and, additionally, the use of design tools had to transcend the professional fields.

The Opera Theatre, in contrast, is an example of a traditional architectural expression being created by a new technology. The traditional character of the architectural expression does not arise from it being realised in many instances, but from the architectural expression already being developed from the beginning of the project. The new technology (the contemporary understanding of acoustics) was allowed to influence the design as long as it did not change the original architectural intention.

The tectonic character of the final edifice of the Minor Hall and the Opera Theatre is not that different. One of the reasons for this, naturally, is the close connection to the Minor Hall project. Especially with regards to the Materiality and Technique, Component and Composition, the tectonic quality is directly inherited from the Minor Hall scheme. Even in connection with the Building Principle it is only the over-pit reflector in the Opera Theatre that can really be criticised as not belonging to both the worlds of acoustics and aesthetics. The tectonic practices, however, are very different.

The design of the Opera Theatre was influenced by the acoustic requirements, which were met through an architectural response. It is, however, also evident from the case that the collaboration took place on each side of the professional split.

Richard Johnson, Jan Utzon and the realisation of Jørn Utzon's intentions

On one side of the collaboration we find the architectural team. In this second case, Jørn Utzon is no longer the sole actor on the architectural side of the collaboration. Rather, there is a whole team of actors consisting of Jan and Jørn Utzon as well as collaborators from Johnson Pilton Walker led by Richard Johnson. Jørn Utzon himself cannot be understood as the same actor in this case as in the last - firstly, because he, due to his age, is no longer the single architect of the project, and, secondly, because his cultural capital today is significantly greater than in the sixties. Also, the relation between the acousticians and the architects has changed so that the field of acoustics has gained influence since then. Where Utzon in the first case was a relatively unknown young architect, time has worked to his benefit. Today it is hard to find any real opposition to the architectural quality of the main concept of the Sydney Opera House whereas in the sixties the project was heavily criticised among architects as well as in the press. Due to this recognition of his principle work, Jørn Utzon has gained world-wide appraisal as an architect. As a result, there is no question that his architectural opinion has a great impact on the current project.

The actual use of the computer is not done by the now 88 year old Jørn Utzon, but by Johnson Pilton Walker. It could have been extremely interesting to know how Utzon in full control of the project and with his fascination with new technology would have taken advantage of the computer as a design tool to create tectonics. Here, however, Utzon's design methodology is carried out by a team of architects with Jørn Utzon himself in the background. Jan Utzon and Richard Johnson equally emphasise that they are attempting to carry out Jørn's intentions even though the tectonic practices show a large discrepancy.

Jan Utzon says about the long standing collaboration between his father and himself, "I am used to it; when he says something and is imagining something in his head, I can imagine the same thing in my head." (Clouds: Jørn Utzon, 1994, author's translation). Likewise, Richard Johnson argues that he attempts to place his own person in the background, which is expressed in his response to the following question from the author,

AMDS: "But it must be difficult to work in this in-between situation. I mean, of course you are an architect and you have your own identity and now you are working as a kind of medium for Utzon."
RJ: [with great enthusiasm] "It is not difficult at all, it is fantastic!" (Johnson, 2005a, l. 186-190)

These statements by Jan Utzon and Richard Johnson are important because they reflect Richard Johnson's and Jan Utzon's own conception of a notion that Jørn Utzon was able to work 'through' them. Both Jan Utzon and Richard Johnson express a deep interest in enabling the architecture of Jørn Utzon to come to the fore with them as midwives. There is reason to be critical of this image of transferring Jørn Utzon's architecture through collaboration, however. Both Jan Utzon and Richard Johnson are architects in their own right and cannot avoid influencing the project themselves. While their fascination and inspiration from the Minor Hall project cannot be questioned, their ability to let Jørn Utzon's approach to tectonics continue through them can.

Jan Utzon's and Richard Johnson's involvement with Jørn Utzon endows the refurbishment of the Sydney Opera House with an authority that would have been difficult to achieve without Jørn Utzon's involvement – this can for instance be noticed in Nicol's and Johnson's reference to Jørn Utzon's acceptance of the over-pit reflector. At the same time Jan Utzon and Johnson are jeopardising their own professional reputation because they – as Peter Hall before them – can be criticised for not being able to realise Jørn Utzon's intentions. This position of the actors as well as a great fascination with the Minor Hall proposal may explain why the architectural team does not stray far from the inspiration from the Minor Hall.

The close reinterpretation of the Minor Hall, however, is precisely the critical point where the tectonic practice of the Opera Theatre distances itself from the practice in the creation of the Minor Hall: where Utzon in the sixties would abandon or completely rework a design proposal if he understood it as opposing the technical requirements, the design team of the Opera Theatre pursues the image of the Minor Hall and will go far to maintain the image of the design even though it is based on an outdated understanding of acoustics.

The actual degree to which Jørn Utzon has been involved with the design of the Opera Theatre is difficult to ascertain. Richard Johnson, however, tells how Jørn Utzon has been spared the day to day jumble of the project and left to work with the design without interference,

RJ: "There are certain things, technical things that you constantly need to absorb and in a way in this project... he can work where I am dealing with those day to day."
AMDS: "You are the buffer?"

RJ: "Yes, I am the buffer. And Jan is the buffer when he is here. And we can both filter and he trusts us enough to say 'so what does all this mean'" (Johnson, 2005b, l. 488-495)

One consequence of this is that Jørn Utzon never deals with the client and the engineers directly, only through Jan Utzon or Richard Johnson,

"His agreement was that all formal communication through Jan, no...no...direct communication to him – other than me – only architect to architect. No managers to architect. They...the management of the house and the project management and the engineers and everybody came to Jan." (Johnson, 2005c, l. 698-703)

To argue that a different arrangement between the actors would have resulted in the development of a new Building Principle would be pure guesswork. The changed attitude towards practicing tectonics might be the result of a changed attitude on the part of Jørn Utzon as well as it may be the result of the collaboration between the architects. What remains, however, is that the Opera Theatre design originated from an involved negotiation between the acoustics and the architecture, but in a completely different collaboration between the actors and their tools than in the Minor Hall tectonic practice. In the design process, the acoustical design tools therefore stay on the acoustical side of the collaboration as opposed to when Utzon took charge over the acoustical design and positioned the ceiling curves according to the reflections.

Arup Acoustics – a design oriented practice

At first glance Arup Acoustics is the ideal acoustic consultancy to assist a tectonic practice. Ove Arup, who founded the company, had studied architecture and philosophy before changing direction into engineering and maintained a strong interest in architecture. Ove Arup had strong ideas about how structural design should be carried out and how it should relate to other professions. He named his approach Total Architecture because it included all the aspects of design in a totality rather than separately.

"The term 'Total Architecture' implies that all relevant design decisions have been considered together and have been integrated into a whole by a well organised team empowered to fix priorities. This is an ideal which can never - or only very rarely - be fully realised in practice, but which is well worth striving for, for artistic wholeness or excellence depends on it, and for our own sake we need the stimulation produced by excellence." (Arup, 1970, p. 2).

Interestingly, the idea of Total Architecture is very similar to the concept of tectonics. One of the consequences of the approach was that the engineers needed to be able to collaborate closely with the architect as well as other actors in the building projects. Murray, who has investigated the Opera House project from Arup's documents remarks about Ove Arup,

"By example, and by his writing he – probably more than anyone else – halted the divergence between architecture and engineering that began in the nineteenth century." (Murray, 2004, p. 18).

This background of the firm seems to be ideal to support a tectonic practice. To presuppose that Andrew Nicol, director of Arup Acoustics in Australasia, who possibly never met Ove Arup, holds the same conception of the practice as the founder of the firm seems unlikely. However, the Key Speech held by Ove Arup (1970) that defines Total Architecture is still mandatory reading to new employees of Arup, is still presented as the central statement to define Arup as a company and must be understood as an important document to guide the professional habitus of Arup today. While Andrew Nicol as an individual has a personal habitus developed through his background, the employment in Arup would also influence him and develop a certain professional habitus. This is evident in many of Nicol's statements as well as in how Arup Acoustics has acted in the design development.

"...when there is a really hard puzzle to solve, they come to people like Arup to solve it because we do have an experience and a reputation for finding solutions to awkward puzzles." (Nicol, 2005a, l. 167-170).

Also, his attitude towards the relationship between the professional fields is similar to Ove Arup's notion of Total Architecture, "...acoustics is not another layer that goes on either underneath or above the architecture, acoustics is very much a part of the architecture." (Nicol, 2005a, l. 430-433). While Ove Arup was very fond of Utzon's manner of taking in other disciplines (Drew, 1999), Andrew Nicol is less inclined to praise Utzon's particular way of collaborating. When asked to compare the process with Utzon and Johnson to another collaborative process he said,

"Richard would explain what he was looking for and we would explain what we were looking for and so there was an interaction as opposed to a transaction. (...) I wouldn't say that either way is...is...is right or wrong." (Nicol, 2005c, l. 188-216).

Consequently, to Nicol, the collaboration with Utzon, which is based on his tectonic intentions, has no special status – rather he sees many different ways of collaborating as equally valid. According to Nicol, the close collaboration between the architect and the consultant is important, but exactly how it takes place, and the architectural intention behind it, is less important.

But collaboration, as such, is emphasised by Andrew Nicol a number of times and also influences how he sees his own role as part designer and part engineer. This role of the acoustician is closely connected to the advances in acoustic knowledge. The influence on the acoustic quality of the exact geometry of the hall has grown during the last century, and therefore the strong acousticians are those who are able to influence the design at an early stage. This new understanding has rendered the field of acoustics one of increasing importance,

"...at that time the architects had more to say than the musicians and the engineers and the acousticians. Today they haven't." (Jordan, 2004, l. 409-411).

"We've always had influence over certain types of projects, particularly where acoustics is...is, is of critical importance...ehm...and there has been a growing respect for acoustic consulting as a discipline over the

last twenty years. (...) It started as an engineering type of focus but shifted much towards design and influencing design. And the strong acousticians that are working around the world now are the people who actually are able to design and draw rather than just to be able to talk about numbers." (Nicol, 2005c, l. 249-260).

One of the reasons why the acousticians are bestowed with greater influence in architectural projects is their increased ability to accurately evaluate the acoustics of an un-built auditorium – an ability that is closely related to the use of the computer. This is recognised by the architectural team, "It is easier, perhaps, to get it right with the tools available today." (Utzon, 2005, l. 236-237).

The tectonic practice in this case was different than in the Minor Hall case. Therefore, the collaboration between the architects and acousticians were different as well. Arup Acoustics supported the early stages of the design with advice and design tools and therefore seems to have been able to support the development of a new Building Principle in a manner similar to how Cremer and Gabler did it. This was, however, not the intention behind the Opera Theatre project. The manner that Arup Acoustics supported the design was therefore different from Cremer and Gabler's manner in that they were less concerned with enabling the architects to work with acoustics on their own. In this design development, the role of the acoustician was primarily to correct the Minor Hall inspiration in order to realise the Opera Theatre as a world-class auditorium.

Design tools supporting each profession

The use of design tools in the process reflects this tectonic practice. Arup Acoustics was easily able to support the collaboration at an early stage in the design, and the manner that Arup Acoustics use design tools throughout the design process clearly reflects an intimate understanding of the architectural process and what is needed to support the design development. The acoustic consultants and their use of design tools are thus supportive of a tectonic practice even though the architects do not use the design tools to work with acoustics independently in their design.

The design tools used are closely connected to the level of development of the design. Firstly, the Design Guide is issued to support the preliminary design, secondly, the first schemes are commented on with geometric advice, thirdly, by simple, quick polystyrene models, and, finally, the more developed schemes are subjected to detailed modelling in computer simulation programmes. Only design tools that respond to the level of development of the architecture are used in each design stage – an ability that in the first case was found to be able to support a tectonic practice.

The use of computer programmes by the architects and acousticians were in at least two instances helpful to the communication between the actors. The fabrication of the polystyrene models was supported by the computer. Likewise, the acousticians' acoustical simulation programmes used the architects' digital models for evaluation instead of having to build new digital models. The obvious benefit of the acousticians' computer simulation is the speed and economy of the design tool that in turn enables an extensive use.

While the computer simulation can be used extensively, it is still inadequate to support the interrogation of the very first sketches. Instead of the computer, a number of other design tools were used to push the design in its early stages. The design guide, the geometrical measuring, the simple ray-tracing by hand and model-analysis with laser were quick design tools that enabled a rapid response to the architects' sketches in the process.

Significantly, however, all the acoustic design tools were used by the acousticians rather than the architects. While the design tools used by the acousticians were developed to suit all stages of the design process, neither the polystyrene models nor the computer simulation were used by the architects to work with acoustics. The complexity of the computer simulation programme entails that it would not have been immediately accessible for the architects. In contrast, the polystyrene models could quite easily have been used by the architects to understand their design – and possibly use the knowledge as a basis for developing a new Building Principle. The fact that the architects did not use the design tools by themselves should be understood in connection with the tectonic practice that does not aim at developing a new Building Principle.

In this case, the computer programmes are not used to cross the disciplinary boundaries. Information is passed between the professions with the assistance of the computer, but the computer does not directly support a tectonic practice by enabling the actors to work with the knowledge of another field.

CONCLUSION – ARCHITECTS AND ACOUSTICIANS AS CO-DESIGNERS

This case describes the design process leading to the creation of the auditorium the Opera Theatre. The tectonic approach of this auditorium is inspired by the Minor Hall created by Jørn Utzon in the sixties and the same approach to tectonics in Materiality and Technique, Component and Composition as well as in Building Principle is used. Therefore, the tectonic quality of the result is in many respects equal to that of the reference.

In connection with tectonics in the Building Principle approach, the use of the Minor Hall reference is somewhat strained because of the degree to which the field of acoustics has changed since the sixties. Some of the significant traits of the Minor Hall Building Principle such as the segments of the ceiling pointing towards the same point on stage and creating a fan-shaped plan are in opposition to the knowledge of acoustics today. Through a close collaboration between the architects and acousticians, however, the Minor Hall Building Principle is nudged into being a contemporary acoustical auditorium that maintains the same acoustic Building Principle. Only one element – an over-pit reflector – can be pointed to as being an element that is only present due to the acoustical requirements. Like the Minor Hall, the rest of the auditorium is a tectonic solution in the Building Principle approach where the technical concerns and the architectural expression are one.

The Building Principle was determined from the outset of the project, and therefore the manner that

tectonics is practiced in the case is different than in the Minor Hall case. The collaboration between the architects and acousticians as well as the use of design tools in the case should be understood from this context. The acousticians played a great part in the design process by suggesting changes to the geometry of the hall. This was underlined by the use of design tools – only the acousticians worked with the analysis and evaluation of the schemes from an acoustic point of view.

The design tools used by the acousticians were easily able to support the design process in the early stages, which was a trait that was found to be important in the last case. In several instances the use of the computer by the architects and the acousticians supported the communication between them, and the design tools were quicker and less expensive to use than in the Minor Hall case. The computer simulation programmes of the acoustician, however, still had their shortcomings and had to be supplemented by other cruder tools in the first stages of the design.

The computer tools of the acousticians as well as of the architects are not used to cross the boundary between the professions. Instead, the model that best characterises the relationship between actors and design tools is that of figure 11 on page 89, where the design tools enable the professionals to work more efficiently in their own field.

This kind of collaboration is not necessarily problematic, but it can be if the acousticians do not understand the tectonic intention of a project. As well-meaning as Arup Acoustics are, Andrew Nicol demonstrates clearly that he does not judge the difference in value of differing architectural expressions. Therefore, it is questionable to expect him and other engineers with no training or even interest in the tectonic tradition to enable a tectonic practice on their own initiative – this is still dependent on the architects or a close collaboration.

Conclusively; the new computer technologies make the tectonic practice easier but are not determinant for whether it is possible to create tectonics. While the technologies have improved and made calculations easier, it is still the human ability to supplement these design tools that is the significant factor for enabling a tectonic practice.

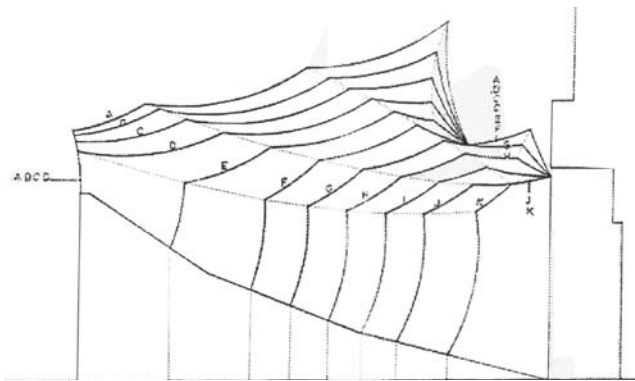


Figure 1: Final Minor Hall scheme



Figure 2: Opera Theatre scheme, February 2005

CASE COMPARISON

In the following the cases are compared. The aim of this comparison is to learn more about the role of the design tools in the tectonic practice. This understanding of the role of the design tool is a stepping stone towards becoming able to discuss the potential of the computer in connection with the tectonic practice.

Firstly, the comparison will focus on the tectonic character and the role of technology in the two practices. This is an important frame for understanding the design developments. Secondly, the design developments of the two cases are compared stage by stage. In this comparison the aim of the cases as well as the role of the design tools and the actors are juxtaposed and discussed throughout. At the conclusion of the comparison, the role of the actors and the role of the design tools are analysed separately.

The similar tectonic edifices of the Minor Hall and the Opera Theatre

The architectural schemes of the Minor Hall and the Opera Theatre are quite similar in appearance and the inspiration from one to the other is evident. Due to the inspiration from the Minor Hall on the Opera Theatre, the tectonic quality of the two schemes is also quite similar. This is demonstrated in each of the three tectonic approaches; Materiality and Technique, Component and Composition, and Building Principles.

In the tectonic approach of Materiality and Technique, the character of both halls is comparable. They are both seen as pieces of furniture positioned on the podium, and this character is underlined by the use of plywood. The lightweight material contrasts the concrete arches of the sails and the heaviness of the podium. The use of plywood in both the Minor Hall and in the Opera Theatre solves the acoustic sound insulation and the structural rigidity of the segments in one move because the necessary number of layers of plywood for the sound insulation is sufficient for the structural rigidity.

Likewise, Utzon's idea of the Minor Hall as one giant jigsaw puzzle in space is maintained in the Opera Theatre scheme. This results in a similar approach to Component and Composition in the two cases. The curved ceiling of the auditoria resembles suspended lengths of textile and gives the spaces a festive atmosphere in addition to directing the attention of the audience towards the stage. At the same time the ceiling curves in each proposal are also pragmatic responses to an industrial building process. The halls are conceived as industrial products that can be produced as prefabricated elements in a factory, leaving only the actual assembly to take place on the building site. Every ceiling curve is an individual element that has a structural height, enough material to insulate for acoustic purposes and is decorated with gilding and colours before it leaves the factory. The joints of the elements are inspired by the use of layered sheets of plywood. In one of the two adjoining elements two sheets of plywood are left out where the other element has two protruding sheets of plywood. Thus, the fabrication of elements allows adjoining elements to be weaved together and locked in a jigsaw-like assembly process.

The Building Principle used in the two halls is equally similar. This applies both to the structural and the acoustic inspiration to the form. The structural principle of the auditorium's plywood segments spanning from the proscenium to the back of the hall is thus present in both the Minor Hall and the Opera Theatre. Also, the inspiration from acoustics has been used in a similar manner in the two halls. The ceiling curves

are convex to disperse the sound energy, and each curve can be positioned to achieve the best distribution of sound to the audience. The aim of this approach is to let the acoustic requirements develop the architectural form. Thereby, the Building Principle is not only created with a visual character of the auditorium as the aim. Inherent to the visual character of the space is the solution to the acoustic requirements – the two aspects become one and the same. This acoustic Building Principle is present in both halls. This is true even if a new acoustic Building Principle could have been called for in the Opera Theatre due to the contemporary understanding of acoustics as opposed to the sixties when the Minor Hall was created.

In all three tectonic approaches, then, the two halls are quite similar.

The dissimilar tectonic practices of the Minor Hall and the Opera Theatre

With similar tectonic edifices one would perhaps expect similar tectonic practices as well. But the similarity of the two tectonic edifices is actually caused by a difference in the tectonic practices. Where the tectonic practice in the Minor Hall aimed at creating original solutions in all respects, including the acoustically inspired Building Principle, the aim of the Opera Theatre process was to adjust the Minor Hall Building Principle to become functionally and acoustically contemporary. There is as such a difference in the architectural approach that can be described by the concepts from chapter three on the relation between technology and architectural expression.

Minor Hall: New technology ←————→ new architectural approach

Utzon was inspired by technology in general and by the acoustic requirements to the Minor Hall in particular. He used these requirements to develop his Building Principle with the sound dispersing off the ceiling curves fanning out from the stage. He could not use the traditional technology from the classic auditoria, firstly, because they did not fit geometrically into the cavity of the sails and, secondly, because they were not coherent with the architectural language of the rest of the Opera House. Instead of using the traditional technology of the classic auditoria, Utzon developed a new auditorium prototype that, in its architectural expression, was appropriate to his Opera House and solved the acoustic requirements. It is clear, then, that the Minor Hall case is an example of a tectonic practice in which both the technology and the architectural approach were new. Andrew Nicol ascertains that no similar ceiling has been used for an opera hall before and Richard Johnson wonders why no one has attempted to work from the architectural principle. Indeed, one searches in vain for a similar architectural and acoustic approach in other works of architecture.

Opera Theatre: New technology ←————→ traditional architectural approach

The Opera Theatre, by contrast, is an example of a traditional architectural expression being created by a new technology. The architectural approach is traditional in the sense that the close interpretation of the Minor Hall case signifies that the architects are attempting to maintain the architectural expression of the Minor Hall even though the acoustical premises that it was based upon have changed. This is true even though the Minor Hall was never realised and the Opera Theatre would become the first example of such an auditorium. The strong inspiration from the Minor Hall meant that the architectural expression that the project was aiming for was already decided upon before the design process was initiated. The architectural scheme has been developed with respect to the new acoustic and functional requirements, but the archi-

tectural inspiration from the Minor Hall was never abandoned. Because the architectural expression was determined from the outset, the architectural approach can best be characterised as traditional.

Traditional technology \longleftrightarrow traditional architectural approach

Traditional technology \longleftrightarrow new architectural approach

The two cases are examples of two different relations between technology and architectural approach. Beim (1999, 2004) describes two other relations as well; traditional technology \longleftrightarrow ~~new~~ architectural approach and traditional technology \longleftrightarrow traditional architectural approach. While these were exemplified in connection with architecture in general in chapter three, it is worthwhile to pause on how these relations would manifest in connection with auditorium design. The relation between traditional technology and a new architectural approach is a common approach in auditorium design. Often, the auditorium type is described minutely in the competition brief leaving only little room for changes by the architects and acousticians. In effect, then, the auditorium has been designed before the design process of the rest of the building actually begins. At least two examples of auditoria designed with this approach are being built in Denmark; Aalborg House of Music where the auditorium prototype was the shoebox-shaped Musikverein in Vienna, and the Danish Radio where the vineyard-shaped Berliner Philharmonie was the prototype. Contrarily, the relation between a traditional technology and a traditional architectural approach is rare in connection with auditoria. Often, music houses and theatres are expected to be architectural landmarks demonstrating a new architectural approach – even in the cases where the auditorium prototype has the same technological substance as the historical precedents.

The similarity of the two tectonic edifices of the Minor Hall and the Opera Theatre and the discrepancy between the tectonic practices underline one of the central themes of the present research; that the tectonic practice is fundamentally different from the tectonic edifice and reveals something that is not accessible when tectonics is only addressed through built architecture. Especially in connection with the discussion of the role of design tools, tectonics as a practice becomes important.

THE TECTONIC PRACTICE – DESIGN TOOLS AND ACTORS

With this initial understanding of the two cases as two different tectonic practices, a closer analysis of the cases is carried out in the following. To illustrate the two cases, two crude but illustrative diagrams are seen in figures 3 and 4. The figures illustrate the two design processes in terms borrowed from Broadbent (1988), who sees the design process as spanning from the briefing stage to the implementation stage. Broadbent's understanding of the design stages is very schematic and should not be understood as a reflection of how the design process is experienced by architects and acousticians. Despite their crude nature, the diagrams are beneficial as an illustration of the differences in the design developments.

Apart from tracing the processes according to Broadbent's stages, the use of design tools is also added to the diagrams – except from the pencil and physical model of the architect, which are left out for the sake of clarity in the diagrams. The design tools that were used during the processes are indicated with the full

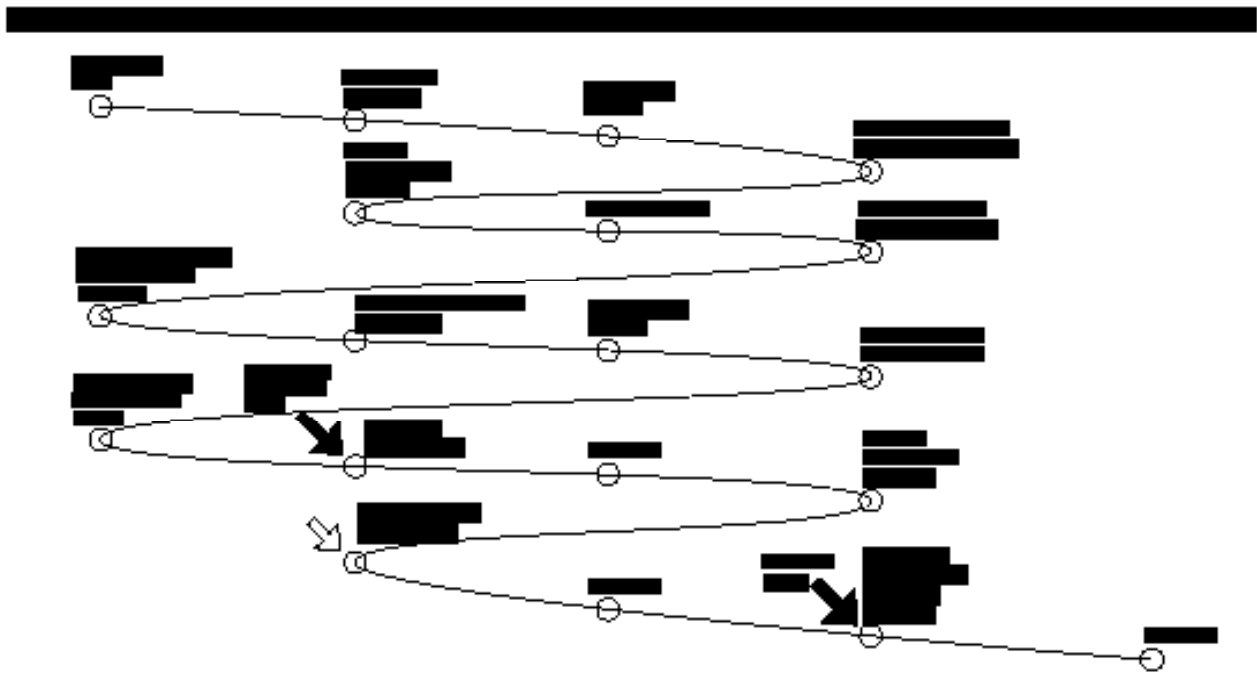


Figure 3: Diagram of the Minor Hall design process

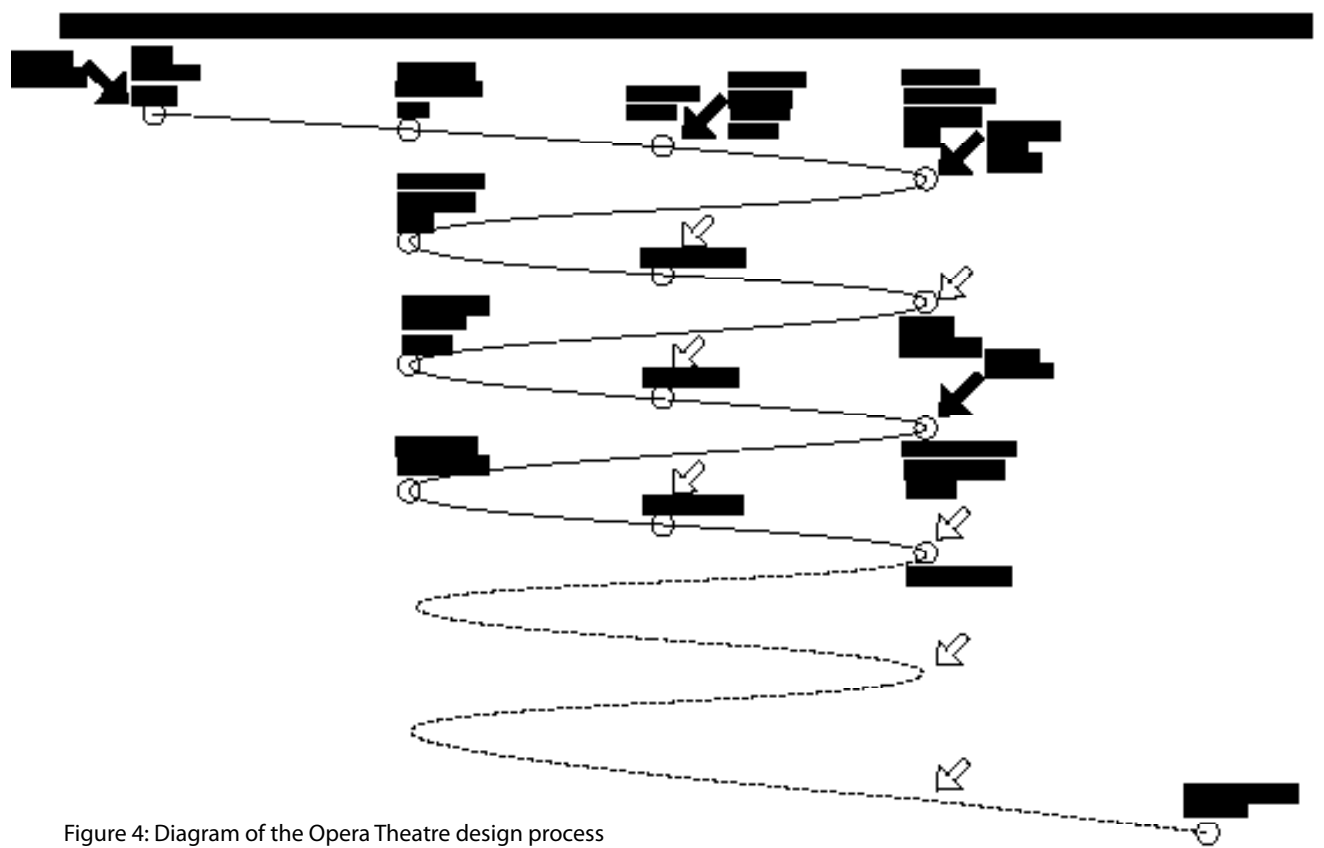


Figure 4: Diagram of the Opera Theatre design process

arrows attached to the point in the process when they were used first and outlines of arrows the times they were subsequently used.

The diagrams clearly demonstrate that the design processes and the use of tools differ between the cases. Where the two case chapters describe the iterations of the design developments (the curved lines in the diagrams), the analysis of the cases in this chapter will compare the cases stage by stage from left to right in the diagrams. This will reveal how the stages of the two practices differ and how each kind of practice is enabled by actors and tools differently. Therefore the relation of technology to architectural approach is an important frame of reference to be used when discussing a future tectonic practice supported by digital tools. Through the comparison of the cases, it will be shown that it is especially in the transition from the evaluation stage to the analysis stage that the practices differ.

Brief development stage

The briefing stage is the time in the process where the actors are briefed about what the architectural scheme should solve or emphasise. In Broadbent's understanding this brief is external and coming from the client. In the Opera Theatre case, however, the brief is developed by the practitioners in collaboration with the client. Therefore the stage that Broadbent calls the Briefing stage is here called the Brief Development stage to encompass a notion that the brief is not a fixed and static thing, but rather something that can develop.

One of the clear discrepancies between the cases can be seen in this stage where Utzon in the Minor Hall went back to this stage a number of times in order to understand the field of acoustics. Jordan had briefed Utzon on the acoustic requirements of the Minor Hall as he saw them. Not only did he explain the necessary proportions and volume in words, he also demonstrated them in the Red Book scheme. This interpretation of the brief was, however, based on a traditional use of technology because Jordan worked from the classic auditoria. What Utzon wanted to do was to develop a new auditorium prototype because of the difficult geometry of the cavity under the sails. In order to do this, he needed to understand the acoustic requirements himself and not through Jordan's interpretation. Therefore, Utzon went back to the brief development stage in an attempt to understand the background for the requirements that Jordan asked for. Similarly, when Cremer and Gabler became involved in the case he asked them to brief him on the fundamentals of acoustics. The loops back to the briefing stage are therefore a sign that Jordan's initial explanation of acoustics was not instrumental in Utzon's work. Likewise, they show that this stage of the design is important in a tectonic practice that attempts to create a new architectural approach by using new technology (in this case a contemporary understanding of acoustics). In such a tectonic practice it was necessary to understand the fundamental rules of acoustics well enough to be able to work with them architecturally.

In comparison, the Opera Theatre process did not loop back to the brief developing stage. Like Jordan's advice, the Arup Acoustics guide was based on the classic auditoria. If the aim of the Opera Theatre case had been similar to the Minor Hall case, it could therefore be expected that Johnson and the Utzons would need to go back to the brief development stage like Utzon did in the Minor Hall case. But the Opera Theatre

case did not loop back to the briefing development, and this discrepancy can be explained by the differing aims of the cases. In this case where the aim was to update an already developed Building Principle to a contemporary understanding of acoustics, the briefing information that the architects got from Arup Acoustics was detailed enough for the architects to work from. Therefore, they were not attempting to understand the fundamental rules of acoustics as Utzon did in the sixties. To a tectonic practice that works from a given Building Principle, the brief development stage is as such not as important as in one that attempts to develop a new Building Principle.

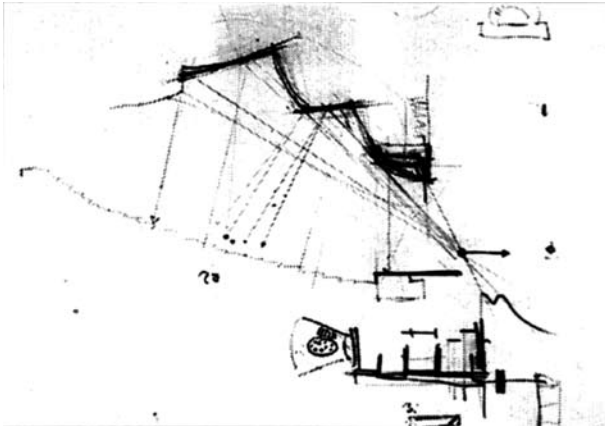
Analysis stage

In the analysis stage the information from the requirements of the brief is analysed. In a competition project the analyses might be carried out in order to understand the restrictions of a building site and the content of the functional requirements. The analyses are used to develop the architectural form, not as a deterministic result logically derived from objective analyses, but by circumscribing the field of solutions within which the architect can work. The stage could therefore also be called the formative stage of the design. Depending on the architectural approach, technology may be an aspect that is analysed.

In the Minor Hall case Utzon was determined to develop an architectural scheme where the acoustic requirements were an inherent part of the architectural expression. In this stage it was therefore important for him to form his architecture from the fundamental acoustic rules. While Jordan was a pioneer in the ability to evaluate the acoustic quality of a given architectural scheme, he did not have any experience in supporting the analysis stage where the architectural scheme was developed. Instead, Utzon attempted to be inspired to an acoustic solution by studying other architectural projects. The experience in supporting a design development to solve the acoustic requirements inherent in the architectural form was, however, what Cremer and Gabler had. They supported Utzon's aim by directing his design and instructing him on the relation between direct and reflected sound. By understanding this fundamental rule of acoustics, Utzon could analyse his own designs and form his architecture to meet the requirements. The formation was not deterministic because the relation did not only result in one solution. Instead, it gave Utzon an inner and outer boundary between which he could form his auditorium ceiling freely. The design tool provided by Cremer and Gabler and developed by Utzon enabled him to develop a new Building Principle where the new acoustical knowledge resulted in a new architectural expression.

In the Opera Theatre the aim was not to develop a new Building Principle, and therefore the architects were not concerned with understanding the acoustic field to an extent that let them work with the field on their own. The architects understood the acoustic requirements and the means through which the acousticians attempted to solve them (less radial plan, flatter ceiling etc), and they changed the architectural form accordingly. It was thus through a collaborative effort that the design developed into a contemporary world-class auditorium. The architects did not work with acoustics in order to develop a new auditorium prototype but as the reason to change the auditorium geometry incrementally. This is especially evident when the Minor Hall curvature of the ceiling was re-introduced. Acoustically, there were still problems with the curves, but the inclination towards using the same architectural expression meant that these problems were solved through subsequent corrections (lighting slots and over-pit reflector) instead of addressing it through a

Figure 5 and 6: The drawing of reflection paths and the evaluation of the polystyrene models worked in much the same way but in the Minor Hall the design tool was used by Utzon to form his architecture, in the Opera Theatre by the acousticians to evaluate the acoustic quality.



changed Building Principle. Due to this approach, the findings from the evaluation stage were not used as a design tool in this stage of the design. There were numerous analyses in the Opera Theatre case; the architects for instance analysed various circulation patterns and manners of positioning the audience. The acoustic analyses that were carried out were, however, done by the acousticians and not the architects.

Synthesis stage

In the synthesis stage the findings from the analysis stage are joined into an architectural scheme. As mentioned, this synthesis rarely occurs as a simple conclusion to the analysis. Rather it is a creative work where the architect often has a lot of freedom within the limits found in the analysis.

In the Minor Hall competition scheme, the Red Book scheme and the stepped cloud scheme, primarily focused on either acoustics or the architectural requirements, while scheme III and IV created a synthesis between the two. The aim that was strived for and finally achieved was a scheme that through the architectural form solved all functional, technical and material concerns in one gesture.

In the Opera Theatre the synthesis between the acoustics and the architectural expression was present from the first scheme due to the re-introduction of the Building Principle from the Minor Hall. Consequently, the subsequent syntheses were subtle changes to the first scheme in order to improve its acoustic quality. In this quest the architectural computer modelling of the schemes for visualisation and geometric manipulation were used extensively to communicate with the acousticians.

Evaluation stage

In the evaluation stage the scheme is evaluated – in this case at least with regards to architectural expression and acoustics. In contrast to the analysis stage where the various aspects are used to form the architectural form, the evaluation stage is not concerned with creating form but with determining whether the result is acceptable and enjoyable as it is, or whether it should be changed.

Jordan and Cremer and Gabler would evaluate the schemes in this stage, initially by simple measuring of volume and reflection and later by the scale model testing. In order for Utzon to develop his auditorium, the evaluation stage where the schemes were rated by the acousticians as well as by Utzon himself was important. The primary tool that was available to support this stage in the Minor Hall case (the scale model testing) was not adequate to evaluate the early schemes. In order to build a physical 1:10 model of a scheme, it had to be developed in great detail and the cost and time consumption of the scale model testing limited the use of this tool. At that time, then, the evaluation tool had its limitations. Nevertheless, this stage of the design was one that Jordan was easily able to support. He had pioneered the scale model testing and was one of the leading figures of this method in Europe. The fact that Utzon chose to hire another set of consultants anyway testifies that it was not only the evaluation in itself that was important to Utzon's tectonic practice. This is underlined by the fact that Cremer and Gabler's primary tool for evaluating acoustic quality was, like Jordan's, scale model testing. The aim of developing an architectural expression from the acoustic requirements depended on the evaluation of the schemes, but even more on the translation of the findings. Only Cremer and Gabler would translate their findings into design advice that enabled Utzon to understand how he could improve the acoustic quality of the schemes through architectural means. Cremer and Gabler's reversal of the concave ceiling curves into smaller, convex curves as well as the instruction on the relation between reflected and direct sound were directly usable in the analysis stage to create an improved scheme. So, to an architectural approach that attempts to develop a new Building Principle the evaluation stage is important but the translation of the findings in the evaluation stage is even more crucial.

In the Opera Theatre, the acousticians had at their disposal the computer simulation programmes. This gave the acousticians the opportunity to test the architectural schemes much more frequently and rapidly. The computer simulation, like scale model testing, does not support the evaluation of the first undetailed schemes, and therefore this tool was supplemented by polystyrene evaluation models. But these two tools in combination were ready-to-hand tools to support the evaluation of the architectural stages from the early sketches to the detailed schemes. The many times these design tools were used in the Opera Theatre case demonstrate how the new tools have rendered it much easier to evaluate the acoustic quality of the architectural schemes. Where the Minor Hall evaluation tool was only used once, the computer simulation was used to evaluate nine to ten schemes. The new tools should as such be seen as one of the explanations to the many loops between the analysis and the evaluation stage in the Opera Theatre case. Every time the acousticians evaluated the architectural schemes and identified a new problematic area (the angle of the sidewalls, the curvature of the ceiling, the volume available) the architects would attempt to revise the scheme accordingly in order to achieve the best acoustic quality possible. As Jan Utzon says, (Utzon, 2006, I. 236-237) it is much easier to get the acoustic quality right with the design tools available today. However,

the application of the design tools in the evaluation stage is also a consequence of the aim of the Opera Theatre case. The aim here was not to develop a new Building Principle, but to update the Minor Hall principle to a contemporary understanding of acoustics. In this quest the evaluation stage of the design is important to support because it was in this stage that the changes necessary to the existing Building Principle were established. The decisive difference between the two cases is that where the findings in the evaluation stage in the Minor Hall case were translated into advice that Utzon, as an architect, could form his Building Principle from, the advice in the Opera Theatre case was used by the acousticians to adjust the existing Building Principle. In this practice, the acousticians became co-designers because they, together with the architects, decided which way to proceed (less fan-shaped plan, larger volume, flatter ceiling etc) in order to make the Minor Hall Building Principle work. The findings from the evaluation stage were not used by the architects themselves to understand how the acoustic quality could be improved through architectural means, but they developed the existing Building Principle from the acoustic advice they got from the acousticians. In a project where the aim is to nudge an existing Building Principle into place, then, the evaluation stage is of great importance because the findings can point directly to which detail, angle or surface is the cause of a problem and needs to be altered.

Implementation stage

If the criticism of the evaluation stage can easily be implemented in the scheme, this is done in the implementation stage. If not, the design loops back to the analysis stage or even to a new briefing stage. The implementation stage is thus simply the ending point of the design where the architectural, acoustical and other requirements are seen as sufficiently developed.

Crucial stages to support

To conclude, it is evident that the aim of the tectonic practice determines which stages of the process are important to support and how they should be supported. The primary difference between the two kinds of practices is found in the transition from the evaluation stage to the analysis stage.

The kind of tectonic practice that Utzon conducted in the Minor Hall case (new technology and new architectural approach) depended on the evaluation to be translated into principles that could be used in the analysis stage to develop the architecture. Likewise the kind of tectonic practice of the Opera Theatre (new technology and traditional architectural approach) depended on the evaluation stage to reveal how the architectural form could be improved. What was sought in the Opera Theatre case, however, was not an understanding of how to radically change the Building Principle, but an understanding of how incremental changes could improve the acoustic quality. The findings from the evaluation were subsequently used by the architects to correct the scheme.

The manner, in which each tectonic practice is enabled, then, depends on the various aims of the cases. When the aim of the project is to develop a new architectural approach as a response to a new technology, it is especially the formative part of the design in the analysis stage that should be supported. When Utzon understood how the acoustic requirements would affect the architectural scheme, he would attempt to develop the next architectural scheme in a manner where the solution to the acoustic requirements was

inherent in the architectural shape. In the Minor Hall case, this kind of tectonic approach was enabled through the acousticians' translation of the findings from the evaluation stage. From these findings, the acousticians developed a crude design tool that enabled Utzon to use these findings in the formation of the architectural form in the analysis stage.

When the aim of the project is to develop a traditional architectural approach through a new technology, it is the evaluation stage that is very important to support. In the Opera Theatre case it was through the evaluation that the problematic areas could be identified, and from the evaluation that the incremental changes necessary could be pointed out. This kind of tectonic practice, then, is enabled primarily in the evaluation stage. The findings need to be interpreted by the acousticians, but because the form is more or less decided upon, this is achieved through literal suggestions for changes to the geometry rather than by conveying an intimate understanding of the acoustic principles to the architect.

With the similarities and differences between the two tectonic practices unfolded, it was demonstrated that a tectonic practice is not just one kind of practice, but varies with respect to the use of technology and the architectural approach. With this understanding as a reference, the following will present a discussion of how the role of the actor and design tools supported these practices.

Actors and the ability to enable a tectonic practice

As was already concluded during the two case studies, the architects and acousticians are the primary enablers of the tectonic practice. Not just through their actions, but also by selecting and using design tools. When understanding the tectonic practice as more than one kind of practice, the role of the actors should be seen in this light as well.

The importance of the actors' professional habitus was very obvious in the Minor Hall case where Jordan found it difficult to support the early design process even though he was one of the best acousticians of his time. This lack of design advice in the first stages of the design process meant that in effect Utzon could not develop a tectonic project where the acoustic requirements were an inherent part of the architectural scheme. In contrast to Jordan's hesitation in supporting the actual design, Cremer and Gabler gave advice in the analysis stage of the design. Cremer and Gabler were, then, better equipped to enable a tectonic practice with the aim of developing a new technological approach.

This difference between the acousticians is best explained from their professional habitus. Jordan's relatively traditional approach to acoustics favouring the classic concert halls was difficult to combine with Utzon's architectural approach of developing new Building Principles. Jordan compared Utzon's new prototypes with the classic auditoria, found them to lack in acoustic quality (Jordan, 1980), and therefore wanted to pursue the traditional technology of the classic auditoria. In contrast, Cremer argued that despite the obvious benefits of the guaranteed good sound quality when using historical precedents (the classic auditorium shapes) this approach would be the end of architecture and prevent innovations (Cremer and Muller, 1982). They were therefore supportive of Utzon's quest to use new technology rather than beginning from the classic auditoria.

To be fair, it cannot be concluded that Jordan could not have supported a tectonic practice. If Utzon had worked with the traditional technology of the classic auditoria, or if Utzon had been willing to let Jordan adjust his design to improve the acoustic quality subsequent to the design, Jordan would have been able to supply his expertise and support the tectonic practice. With his scientifically oriented professional habitus, Jordan would in effect have been able to support a tectonic practice as it was carried out in the Opera Theatre case. Where Jordan might seem as the villain in the Minor Hall case, this is far from the truth. He was a skilled acoustician, but there was a mismatch between his professional habitus and the architectural approach that Utzon wanted to pursue.

The conclusion, then, is that an actor's professional habitus cannot be seen as obstructing or enabling a tectonic practice in general. But it can be seen as obstructing a specific tectonic practice because it takes different skills to support the differing tectonic practices. The replacement of Jordan was thus necessary because Utzon wanted to pursue a tectonic practice based on a new technology.

It was Jørn Utzon who was the *primus motor* in determining the tectonic approach of Minor Hall. It is clear from the case development that it takes a determined architect to pursue a new architectural and technological approach because this approach is relatively more problematic than using a traditional architectural approach or a traditional technological solution. Utzon had the cavity under the sails that did not match a classic auditorium as a pragmatic reason for wanting to pursue a different direction with the Minor Hall. However, he also had a professional habitus that made him eager to take advantage of the newest technologies and explore them in his design. This must be said to be the primary enabler of the kind of tectonic practice exemplified by the Minor Hall.

Jørn Utzon's eagerness to develop his architectural expression from an acoustic understanding was less outspoken in the Opera Theatre case. Richard Johnson and Jan Utzon's approach began from the Minor Hall Building Principle. This reflects, according to them, a pragmatic concern with how the cavity under the sails restricts the shape of the auditorium as well as a concern with the conceptual relationship between the original auditoria and the rest of the Sydney Opera House. In addition, however, the approach must be understood as an aspiration to realise the un-built, original interiors of the Minor Hall to demonstrate how the Utzon interiors would have presented themselves if Utzon had not been disengaged from the project in the sixties. Regardless, the architectural approach is decided upon by the architects in this case, and they must therefore be seen as the primary enablers of the tectonic practice.

Like Jordan, Arup Acoustics are inspired by the classic auditoria, and, as Cremer and Gabler, eager to influence the design process. They even perceive themselves as a design consultancy. While Arup Acoustics cannot be said to represent all contemporary acoustic consultancies, they are, according to Andrew Nicol, representative of the strongest acousticians who are able to design and draw rather than only talk about numbers. (Nicol, 2005c, l. 257-260).

What is evident from the case of the Opera Theatre is that it is well within the ability of the acoustic consultants to support a tectonic practice where the focus is on the evaluation stage. It could have been inter-

esting to see Arup Acoustics ability in a design process where the architects were using the new technology to create a new architectural expression. Andrew Nicol clearly understands the importance of affecting the early design process, but would he be able to support the architects in using the acoustic understanding as a design tool? While there is no evidence to support it in the cases, a qualified guess is that the contemporary understanding of the relation between acoustic quality and the geometry of the hall would also enable Arup Acoustics to support a tectonic practice as in the Minor Hall.

In the Minor Hall as well as in the Opera Theatre the architects were the ones who made the decisions regarding architectural approach and whether the technology should be used to develop the architectural form or not. In some cases the acousticians (Jordan) were not able to support the direction of the architects, thereby obstructing the tectonic practice. Other acousticians (Cremer, Gabler, Andrew Nicol) seem to be able to support any given approach that the architects want to pursue. This indicates how important it is to ensure coherence between the acoustician's professional habitus and the architect's architectural approach.

In both cases it was the architects who decided on the architectural approach. Today the architectural interest in creating tectonics is therefore important as ever. Even though the acousticians are able to support a tectonic practice, the initiation of the tectonic practices is still primarily driven by the architects.

In conclusion, then, the role of the actors cannot be understated. No given design tool – digital or not – can be expected to cause a tectonic practice. This is still in the hands of the actors. Therefore, any tectonic practice is still dependent on a conscious approach by the architectural and consulting actors.

Design tools and the ability to enable a tectonic practice

With this said, however, the design tools do have a role to play in the support of both tectonic practices. The design tools cannot by and of themselves enable or obstruct a tectonic practice, but they can be used by the actors in their tectonic quest and thereby support the tectonic practices. An understanding of how the design tools can support each tectonic practice gives the basis for discussing to which degree the computer as a design tool can support these tectonic practices. In the following the role of the design tool is therefore analysed.

In each of the cases the professionals have each their tools relating to their professional field as it is described in figure 7. In the Minor Hall the architects had physical models and pencils as their main tools. In the Opera Theatre these tools had been supplemented by computer programmes to manipulate and visualise the geometry of the scheme. In the case of the Minor Hall the acousticians had scale model testing as their primary tool, and Cremer and Gabler supplemented this with the geometric relation between the direct and reflected sound, which Utzon used as a design tool. In the Opera Theatre case the physical scale model had almost been replaced by the digital acoustic simulation and remained present only in the small polystyrene models.

The key for the acousticians to support the different tectonic practices was to use the right design tool at

the right time. In connection with the Minor Hall case this meant supporting the architect's analysis of acoustics in the formation of the Building Principle in the analysis stage. In the Opera Theatre case it meant supporting the incremental changes to the architectural scheme by evaluating the schemes and identifying the problematic geometries. While the design tools supporting the evaluation stage were equally important in the two tectonic practices, the Minor Hall case was further supported by the design tool in the analysis stage.

The acousticians' support of the evaluation stage through measuring volumes and reflection lines were important to the Minor Hall tectonic practice. Where the practice distinguishes itself from the other tectonic practices is in the support that is needed in the analysis stage. The design tool that Cremer and Gabler supplied Utzon with enabled him to work with an architectural approach from the acoustic understanding. The simple relation between direct sound and reflected sound (as a design tool) was special in the sense that it overlapped between the two professional fields. It was an acoustical rule of thumb, but it was also a geometrical relation that could be used directly in Jørn Utzon's design development. In that sense the tool could be seen as located between the professions as portrayed in figure 8. This kind of shared design tool was important in Jørn Utzon's quest to develop the architectural expression from the acoustic understanding. Through his own analysis of how the acoustic rule of thumb impinged on his design, he could understand it well enough to create an architectural expression that solved aesthetic and acoustic concerns in one. The shared character of the design tools in the Minor Hall case was of great importance. If a design tool should be supportive of this kind of tectonic practice, where the technology and the architectural approach are both new, the ability to work with both fields at once is crucial.

In the Opera Theatre case the tools of the architects and the acousticians were not supplemented by shared tools. In connection with this kind of tectonic practice, it was not crucial that the architects worked with the acoustics independently. This is evident in the Opera Theatre case where Arup Acoustics tested the polystyrene models and used the digital acoustic simulation on their own. Similarly, the design tool of the architect was only used by the architects. Nevertheless, the design tools of the professionals were important enablers of the collaboration. The architectural tools for visualisation and geometrical manipulation were used to build digital models of the schemes that could be evaluated in the acoustic simulation programme by the acousticians. The design tools used in this case enabled a tectonic practice where a traditional architectural approach was updated with a new technology. The use of design tools in a tectonic practice can be characterised by the model in figure 9 where each the professional field works with each its own design tools.

These findings signify that whether the use of design tools is best characterised by figure 8 or 9 does not determine whether the design tools can support a tectonic practice. Both positions of the design tools can support a tectonic practice but not the same kind of practice. The models simply describe two different tectonic practice where the appropriate design tools are equally different.

The research sheds light upon only two of the relations between technology and architectural approach. A qualified guess as to how to support the two remaining ones with design tools can be made. When the

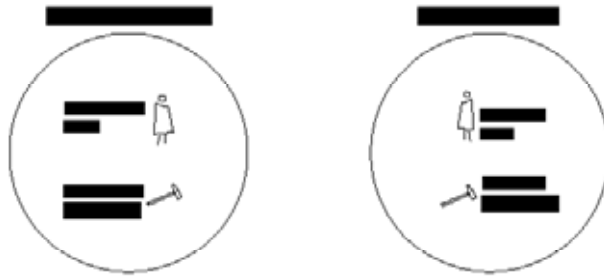


Figure 7: The professionals have an array of design tools to work with in their own field

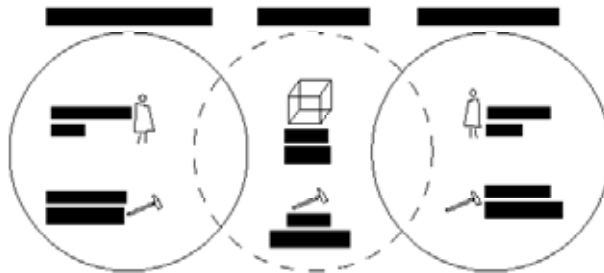


Figure 8: A shared design tool supporting a new technology
 ↔ new architectural approach

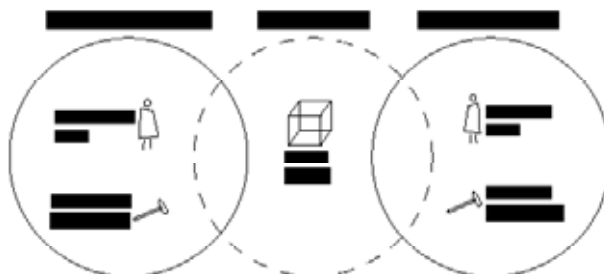


Figure 9: Each field using their own design tools in a new technology
 ↔ traditional architectural approach

technology in a project is traditional; i.e. classic auditoria are used as starting points; the brief development stage would most likely be most important. In this stage the precise size and materials of the auditorium would be described. The evaluation stage would also be important in order to ensure that the acoustic quality would meet the described targets and to assess the impact of minor changes such as material absorption. Because of the precise instructions in the brief development stage, the acoustic evaluation would, however, not necessarily begin as early in the design development as it did in the Opera Theatre. The analysis stage and shared design tools would therefore not hold the same importance as they do in the Minor Hall case.

The comparison of the design process stage by stage demonstrated that in the Minor Hall tectonic practice it was the analysis stage and in the Opera Theatre was the evaluation stage that primarily needed to be supported. In the analysis of the design tools it was demonstrated that it was not only the stage in which the tools were used that was significant. The character of the tools equally differed between the cases; in one case they were shared and in the other they were not. These findings can then be used to discuss the possibilities of the computer in the tectonic practice.

The digital turn of design tools

The case studies showed that in the period of time intervening the two cases, many of the design tools have become digital. This is true of architectural and acoustical design tools alike.

To begin with the acousticians, it was mentioned how the acousticians in the Minor Hall case used scale model testing as their primary tool. Cremer and Gabler supplemented this with the geometric relation between direct and reflected sound, which Utzon used as a design tool. In the Opera Theatre case the physical scale model had almost been replaced by the digital acoustic simulation and remained present only in the form of small polystyrene models.

The evolution of the acoustician's design tools did not jump directly from the large scale model to the digital simulation. The development was incremental. The early models, as in the Minor Hall case, were large using scales of 1:8 or 1:10. As it was also described in the Minor Hall case, these large scale models were inconvenient because of the amount of time it took to build them. In 1979 Barron showed that his method of 1:50 scale model testing was accurate enough to use for measurements of the acoustic quality. To measure with this method, the air in the models had to be dried or replaced with nitrogen, and the first use of digital data in connection with the evaluation of acoustic quality occurred when measurements from these small scale models were fed into the computer and mathematically compensated for the air absorption (Barron, 1979). Contrary to the months the large scale modelling consumed in the sixties, it was possible by then to get results of the first order reflections within a few days (Barron, 2000), and this method has been widely used since. With the introduction of personal computers in the middle of the eighties, the use of computer programmes for pre-calculating acoustical properties increased immensely, and today it is – often in combination with physical scale models – the most common procedure for evaluating the room acoustical quality. The digitalisation of the acoustical design tool significantly cuts down the time consumption and the costs of testing various design concepts from the sixties to the present. The

acoustical design tool has changed not only the speed with which the schemes can be evaluated, but also significantly so the level of confidence in the design tools (Rindel et al, 1999; Pancharatnam and Ramachandraiah, 2003).

The digital model simulation – as it is used in the Opera Theatre case - still has its shortcomings. The digital simulation is most adequate in connection with evaluating detailed architectural schemes. This is demonstrated in the case when Arup Acoustics use polystyrene model analyses in order to address the crude nature of the early architectural sketches. The inability of the acoustical simulation tools' used by Arup Acoustics (Odeon and CATT) to support the evaluation of the early architectural schemes has also been demonstrated by a number of authors (Felmban and Oldham, 2003; Schmidt and Kirkegaard, 2005; Zhang, 2005).

Interestingly, then, the digital tools used by the acousticians have the same characteristics as the physical scale model in connection with the design process. Even though the tool has become easier and quicker to use, it is, in the pre-digital as in the digital era, the same stage of the design that the tools are ready-to-hand in. The scale model testing as well as the digital simulation were ready-to-hand design tools in the evaluation stage of the design process. Here they gave the precise and detailed information necessary at this stage of the design. While computer programmes for acoustic evaluation of the early rough sketches does exist (Turner and Hall, 1990; Turner and Barnett, 1998), they are not applied in the Opera Theatre case. This will be discussed further in connection with how the digital tools support each of the tectonic practices.

Likewise, the design tools of the architects have become digital. As previously mentioned, the architects in the Minor Hall case had physical models and pencils as their main tools. In the Opera Theatre these tools had been supplemented by computer programmes to manipulate and visualise the scheme's geometry. In connection with the tectonic practices described in the case studies, the architects' design tools had lesser influence on the ability to support a tectonic practice than on the acoustician's tools. The digitalisation of the visualisation and geometric manipulation is thus primarily interesting due to the increased ability to share data between the professionals. The architectural design tools have increased the speed of the acoustic evaluation by enabling a direct translation of an architectural digital model to the acousticians' programmes.

The architectural design tools have enabled the architects to work proficiently within their own field. The digital design tools of architects today are numerous, and the ones used in the Opera Theatre case are far from an exhaustive list. The acoustic tools that are used, however, has by a number of authors been described as design tools that are unable to support a design development where the acoustic quality is an inherent concern (Faist et al, 1997; Felmban and Oldham, 2003; Zhang, 2005). Instead, the applied digital architectural design tools address and enhance the architect's ability to work within the architectural field and to communicate digitally with other professional fields. They do not, however, enable the architects to work in the shared field between the professions of architecture and acoustics.

CONCLUSION - ACTORS AND DESIGN TOOLS ENABLING THE TECTONIC PRACTICES

In this chapter it was illustrated how the similar tectonic edifices of the Minor Hall and the Opera Theatre were caused by two different tectonic practices. Where the Minor Hall developed a new architectural expression with the use of the new understanding of acoustics in the sixties, the Opera Theatre used the architectural expression from the Minor Hall, but updated it with a new technology from the contemporary understanding of acoustics. These two tectonic practices were compared stage by stage of the design process. From this comparison it was concluded that the early stages of the design process were very important to the Minor Hall tectonic practice, whereas the Opera Theatre tectonic practice relied heavily on the evaluation stage. The difference was best seen in the transition between the evaluation stage and the analysis stage. In the Minor Hall the evaluation was translated into acoustic rules of thumb that Utzon could use in his design generation, while in the case of the Opera Theatre it was translated into incremental geometric changes to the design.

Subsequently, the ability of the actors and design tools to support these two tectonic practices was discussed. It was concluded that the acoustician's professional habitus could easily obstruct the tectonic practice and that it should be matched carefully with the architectural approach chosen by the architect. It was also concluded that the design tools enabling each of the two tectonic practices had a different character. The development of an architectural scheme inherently solving the acoustic requirements necessitated an intimate understanding of acoustics on the part of the architect, an understanding, which, in the context of the Minor Hall, was obtained through the use of a shared design tool. In contrast, the development of a traditional architectural approach through the use of new acoustic knowledge did not require this intimate understanding, and the architectural and acoustical fields therefore used each their own design tools.

Lastly, it was described how the design tools had developed between the two case studies. The digital acoustical and architectural design tools used were described in terms of their impact in the design process and their ability to work between the professional fields - two characteristics of the design tools that are significant to support the tectonic practices. The conclusion will therefore draw on these findings.

CONCLUSION AND PERSPECTIVES



CONCLUSION AND PERSPECTIVES

In this chapter the research will be concluded. Firstly, a summary will describe the research project. Then the research is concluded by answering the auxiliary and main research questions. Next, an overall conclusion finalises the investigation and discusses the reliability and validity of the conclusions. Lastly, the implications of the study are discussed in terms of the perspectives of the future tectonic practice.

SUMMARY

Introduction

In the introduction it was argued why an understanding of tectonics as a practice is important. The tectonic tradition in architecture is worth maintaining due to the quality of the built environment as well as its ability to develop the building industry. The importance of the tectonic tradition has been emphasised by a number of writers (Frampton, 1982, 1983, 1995; Sekler, 1965; Frascari, 1984, 1991; Gregotti, 1983; Beim, 1999, 2004), but most often these writers focus on tectonics as a quality of the architectural edifice and not as a quality of the architectural practice. The concept of tectonics as it manifests itself in the architectural edifice is conceptually the same today as it was in the master builder era, but the practice to create it has changed fundamentally. If the tectonic tradition should not be seen as antiquated and belonging to a master builder era, it is important to learn more about tectonics as a contemporary practice in order to support the continuing tectonic tradition.

It was showed how the changes to the architectural practice from the master builder to a contemporary context has introduced a number of challenges to the practice of tectonics and made it difficult to create this kind of architectural quality today. One of these challenges is the specialisation in the building industry between architects and consultants that renders it difficult to create architecture where the technical concerns are an inherent part of the architectural expression. The contemporary tectonic practice, however, is able to create tectonics despite these challenges, and an understanding of this practice therefore seems important.

Recently, the writings on digital tectonics have proposed that computer technology should be perceived in terms of the potential it brings to the tectonic tradition. This proposition is the starting point of the study. The investigation into the tectonic practice therefore aims at answering whether the introduction of the computer as a design tool can enable a tectonic practice. The research question is then; to what degree can the introduction of computer programmes for computing, geometrical manipulation and visualisation to the collaboration between architects and consultants enable a tectonic practice?

Methodology

The methodology chapter outlined the research methodology used to investigate this question. In lack of an architectural research tradition, the methodology consists of methods composed from other research traditions, and the primary method is a comparative case study research. In order to investigate the usefulness of the computer in the tectonic practice, a tectonic practice from the pre-digital era is compared to one from the digital era.

The issues investigated are the role of the actor and the role of the design tool in the tectonic practice. Where Bourdieu's notion of the professional habitus is used to understand the actions of the practitioners, Heidegger's notion of the tool as ready-to-hand is used to discuss the appropriateness of a tool at a certain stage of the design process.

The case chosen is the design development of one of the auditoria in the Sydney Opera House due to Jørn Utzon's interest in tectonics. Additionally, the case is appropriate for an investigation of the research question because it spans between the pre-digital and digital era – the first part of the design project by Jørn Utzon was carried out in a pre-digital era in the sixties, while the contemporary refurbishment project by Jørn Utzon, his son and a team of Australian architects has had the benefit of computer tools. Thereby, the chosen case enables a comparative study of the use of design tools in the tectonic practices in a pre-digital and a digital era thus enabling a discussion of the degree to which the computer supports a tectonic practice.

The concept of tectonics

Before carrying out the case studies, however, there is a need to clarify the concepts used and to limit the study – this was done in chapters 3 and 4. In chapter 3, called the concept of tectonics, an understanding of the concept of tectonics was unfolded through the writings of Semper, Bötticher, Frampton and Beim. Rather than attempting to consolidate the writings into one understanding or choosing between the understandings presented, the aim of the review was to outline the range of possible approaches to tectonics. Semper, Bötticher and Frampton's understandings of tectonics were analysed, and it was found that Beim's division into three tectonic approaches can be used to describe the span between the varying understandings of tectonics. The review was therefore concluded by outlining three major approaches to tectonics found in the writings – Materiality and Technique, Component and Composition and lastly Building Principle.

The first approach, Materiality and Technique, is concerned with how materials, the function that the materials have and the technique with which they are processed influence and condition the architectural expression. The second approach, Component and Composition, is concerned with how building components, their assembly and the joints between them influence and condition the architectural expression. The third approach, Building Principle, is concerned with how the choice of structural, environmental and acoustical principles in a building influence and condition the architectural expression. The three understandings of tectonics focus on each their aspect of the architectural edifice. Together, they span from the smallest scale of the material to the largest scale of the organisation of the building. A piece of architecture can be tectonic either by being concerned with all three tectonic approaches or by only focusing on one or two of the approaches.

Relevant to the understanding of the tectonic practice is also Beim's definition of four relations between technology and architectural expression (2004). The tectonic practice can thus be understood as one of the relations: new architectural approach/new technology, new architectural approach/traditional technology, traditional architectural approach/traditional technology, traditional architectural approach/tradi-

tional technology. Within each of the three tectonic approaches it is thus possible to work in a more or less renewing manner. It is, for instance, not technologically renewing to use a post-and-lintel construction, but it can be used to create a new architectural expression. New architectural approaches can also be based on new technologies, e.g. Saarinen's TWA building used the technology of thin concrete shells at the time.

The most common use of the concept of tectonics is within Materiality and Technique and Component and Composition. In the last approach, Building Principles, it is most often only the structural principles that spring to mind in connection with tectonics. Non-structural Building Principles are therefore all the more interesting. Additionally, this kind of tectonics is increasingly relevant because the building industry has become more complex, involving a high number of specialists such as fire, environment and acoustics. While the split between the architectural and engineering professions is a challenge to the two first approaches, the theoretical core of the engineering discipline is full-heartedly applied in this third tectonic approach. Here the theoretical background of the engineers will enable the examination of the architectural scheme as well as the tectonic background of the architects will call for an incorporation of this knowledge into the architectural scheme. The continuing study of the tectonic practice was therefore limited to this tectonic approach that is understood as an architectural expression influenced by the Building Principles chosen.

The concept of tectonics in the digital era

In chapter 4, the concept of tectonics in the digital era was investigated. It was found that the background for the introduction of the concept of tectonics in connection with the digital architecture is that the digital architecture is increasingly being constructed. In this construction the digital architecture needs to address material, components and structural principles to a degree that was not necessary when the digital architecture remained aesthetic experiments in the virtual world (Beesley and Seeböhm, 2000; Ham, 2003; Jabl, 2004; Leach et al, 2004; Gao, 2004; Liu and Lim, 2005a, 2005b). The term tectonic is often used as a headline for these concerns, and it was concluded that the concept of tectonics in the digital era is often understood as another word for building.

The most developed understanding of the concept of tectonics in the digital era was found in the publication "Digital Tectonics" by Neil Leach et al (2004), where it is argued that digital tectonics is a renewal of the Gothic tradition of using structural considerations for developing form. In this quest the digital can be used to generate novel structural forms. The technological novelty of the structural form that Leach points to is, however, limited, and it seems that digital tectonics in this understanding is a new architectural approach, but with a traditional technological substance. In this quest the digital tools can support the structural solution of new architectural expressions. It was concluded that this understanding of digital tectonics has a number of shortcomings. As in the other understandings of digital tectonics, this one points towards rendering the resolution between the technical and the architectural easier but not necessarily on developing an architectural culture of engaging with the technological substance of building as the basis of architectural expression. Also this understanding brushes over the gap between the professional fields and ignores the influence of non-digital design tools.

As another manner of approaching the investigation of the digital design tool in the tectonic practice, two models were proposed (see page 89). The engineering and architectural professions are seen as each their professional field, which have to collaborate in order to create tectonics, and the professions have each their actors and design tools. The models describe two positions of the design tools – one where the design tools support each profession and one where it supports the shared field between the professional fields.

The Minor Hall case

How the tectonic practice and its use of design tools should be understood was then tested in the case studies in chapters 5 and 6. Chapter 5 described and discussed the tectonic practice in the pre-digital era, and chapter 6 presented the same discussion in the context of the digital era. The focus of the case studies was on the development of the auditorium Minor Hall, later called the Opera Theatre. This part of the Opera House is an example of the third tectonic approach because the Building Principle was here developed from the acoustic requirements.

In the design development of the auditorium Minor Hall in the pre-digital era, Jørn Utzon attempted to develop the auditorium as a new architectural expression using a new technology. His first acoustician, Jordan, wanted to work from the traditional technology of the classic auditoria, and he found it difficult to support Utzon's approach. Jordan was a skilled acoustician who had pioneered one of the most advanced acoustic tools at the time, scale model testing, but this design tool and Jordan's professional habitus could not support Utzon in his tectonic practice. Utzon's second set of acousticians supplemented scale model testing by small design tools that could support Utzon in the early stages of his design. Thereby they enabled a tectonic practice. In addition to being ready-to-hand in the early design stages, this design tool had the ability to be positioned between the professions and then be described by the first model.

The case study from the pre-digital era showed that the ability to support a tectonic practice is caused first and foremost by the actors and their professional habitus. The difference in how the acousticians were able to respond to Utzon's quest to create a new auditorium prototype was what made them enable or obstruct the tectonic practice. The design tools are also important in enabling the tectonic practice - in effect Utzon could not have created a tectonic solution to the Minor Hall if only the scale model had been available as a design tool. In this case, however, the crucial design tool was an instruction by Gabler and Cremer on the fundamental connection between reflection lines. The design tool enabled a tectonic practice because it was an acoustical tool that could be used by the architect. As such it was positioned between the professions as seen in figure 10 (see page 89). This served as a ready-to-hand design tool early in the design and made it possible for Utzon to use acoustics to develop a new Building Principle.

The Opera Theatre case

The second case described the design process leading to the creation of the auditorium the Opera Theatre. The tectonic approach of this auditorium was highly inspired by the Minor Hall, and therefore the architectural approach was characterised as traditional. The acoustic prototype used was, however, new because the knowledge of the field has developed since the sixties. Through a close collaboration between the architects and acousticians the Minor Hall Building Principle was nudged into being a contemporary acoustic

auditorium. The Building Principle was determined from the outset of the project, and therefore the manner that tectonics was practiced in the case was different than in the Minor Hall case. The collaboration between the architect and acousticians as well as the use of design tools in the case should be understood from this context. The acousticians played a great part in the design process because, primarily, it was these actors who suggested the changes to the geometry of the hall. This was underlined by the use of design tools – only the acousticians worked with the analysis and evaluation of the schemes from an acoustic point of view.

The design tools used by the acousticians were well able to support the design process from the early architectural sketches, which was a trait that was found to be important in the Minor Hall case. In several instances the use by the architects and the acousticians of the computer supported the communication between the acousticians and architects and the design tools were quicker and less expensive to use than in the Minor Hall case. The computer simulation programmes of the acousticians, however, still had their shortcomings and had to be supplemented by other cruder tools in the first stages of the design. The computer tools of the acousticians as well as those of the architects were not used to cross the boundary between the professions. Instead, the model that best characterises the relationship between actors and design tools is that of figure 10 (see page 89), where the design tools enable the professionals to work more efficiently in their own field. The use of design tools characterised by figure 11 is no less tectonic than the Minor Hall, but it calls for a different character of the design tool. Conclusively, the new computer technologies make the tectonic practice easier, but they do not determine whether or not it is possible to create tectonics. While the technologies have improved and made calculations easier, it is still the human ability to supplement these design tools that is the decisive factor in a tectonic practice.

Case comparison

In the comparison between the two case studies it was showed how the similar tectonic edifices of the Minor Hall and the Opera Theatre were caused by two differing tectonic practices. Where the Minor Hall developed a new architectural expression with the use of the new understanding of acoustics in the sixties, the Opera Theatre used the architectural expression from the Minor Hall, but updated it with a new technology from the contemporary understanding of acoustics. These two tectonic practices were compared stage by stage of the design process. From this comparison, it was concluded that the early stages of the design process were very important to the Minor Hall tectonic practice, while the Opera Theatre tectonic practice relied heavily on the evaluation stage. The difference was best seen in the transition between the evaluation stage and the analysis stage. In the Minor Hall the evaluation was translated into acoustic rules of thumb that Utzon could use in his design generation, while in the Opera Theatre it was translated into incremental geometric changes to the design.

A discussion of what enabled these tectonic practices ensued, and it was concluded that the acousticians' professional habitus can easily obstruct the tectonic practice, and that it should be matched carefully with the architectural approach chosen by the architect. It was also concluded that the design tools enabling each of the two tectonic practices have a different character. The development of an architectural scheme inherently solving the acoustic requirements requires the architect to have an intimate understanding of

acoustics. An understanding that in the Minor Hall was obtained through the use of a shared design tool. In contrast the development of a traditional architectural approach through the use of new acoustic knowledge does not require this intimate understanding, and the architectural and acoustical field can therefore use each their design tools. Lastly, the case comparison was used to describe how the design tools of the architect and acousticians have developed.

OVERALL CONCLUSION

To sum up, the conclusions that were drawn in the various parts of the study will be summarised. This overall conclusion can be read in close connection with the auxiliary questions posed in the introduction.

The first theme of the auxiliary questions was concerned with how the introduction of the computer as a design tool has influenced the understanding of tectonics. The concept of tectonics in a pre-digital era was analysed and it was concluded that the concept encompasses a view of architecture as more than a rational, sheltering commodity and more than an aesthetic choice between styles. Likewise, it entails an understanding of how the human being has shaped its surroundings by gradually exploring and refining the materials and techniques for building. Specifically the concept of tectonics can be grouped into three approaches that focus on each their aspect of the architectural edifice. Materiality and Technique focuses on how the materials influence and condition the architectural expression. Component and Composition focuses on the assembly of building components. And Building Principles focuses on the organisation of buildings according to structural, environmental or acoustic principles. A piece of architecture can be tectonic either by being concerned with all three tectonic approaches or by only focusing on one or two of the approaches. Likewise, it was concluded that a tectonic approach can be more or less renewing by using new or traditional technology as well as it can use a new or traditional architectural approach.

In the digital era the concept of tectonics likewise addresses the three tectonic approaches found in the pre-digital understanding of tectonics. However, in the digital era the concept of tectonics has mainly been used as another word for building. For instance, Neil Leach (2004) has described “digital tectonics” as the way that the computer technology can renew the tradition of using structural considerations to develop architectural form. The digital tools that are used to exemplify this movement are, however, better understood as being in the service of solving technical aspects (structural, acoustic etc) of an architectural project than developing the architectural expression through its technical substance. As such, the concept can be said to lack the notion of architecture as more than a rational or stylistic endeavour that can be found in the pre-digital understanding.

Digital tectonics, it was concluded, thus has some shortcomings in its description of how the computer as a design tool can influence the tectonic tradition. The computer as a design tool is used within all three tectonic approaches and should as such influence the tectonic practice. In opposition to the digital tectonic manifest, it is proposed to understand the role of the computer as a design tool through an investigation of the tectonic practice where human actors as well as design tools interact.

In line with this, the second theme of the auxiliary questions was concerned with the tectonic practice and the role of the human actors and design tools in this practice. From the outset of the study, the tectonic practice was expected to be characterised by the human actor as well as the design tools. This was confirmed through the case studies. Also, however, the tectonic practices differ according to the use of new/traditional technology and new/traditional architectural approach.

Primarily, the actors and their professional habitus is what enables or obstructs the tectonic practice, and therefore the professional habitus of the actors involved should be carefully considered in connection with the aim of the project. Again, however, what enables and obstructs a tectonic practice relates to which specific tectonic practice is in question because they need support in different stages of the design. The design tools themselves can not completely obstruct the tectonic practice because the actors can supplement the available tools. The design tools can, however, support the tectonic practice by being ready-to-hand in the right design stage.

The design tools in the first case were not digital. Moreover, they were slow, costly and present-to-hand in the early stages of the design. Utzon's aim with the project was to create a new architectural approach and technology. Therefore it depended on support in the first stages of the design process in order for the architect to become able to develop the architectural expression from an understanding of the fundamental rules of acoustics. The first acoustician, Jordan, was not able to support this tectonic practice. He was inspired by the classic auditoria, and his professional habitus and subsequent use of design tools was based on working with these as a starting point. In comparison, Utzon's next consultants, Cremer and Gabler, were able to support the tectonic practice because they had developed new auditorium prototypes before. It was therefore concluded that it was primarily the individual actors who enabled and obstructed the tectonic practice in this pre-digital case. Furthermore, it was concluded that in order to support a tectonic practice with the aim of creating a new architectural expression with a new technological approach, it was the formation of the architectural form that the design tool should support.

In the digital era, the design tools are digital and thereby swifter, less costly and ready-to-hand earlier in the process. The aim of the project studied was to develop a traditional architectural approach from a new acoustic knowledge. The tectonic practice depended on the support of the evaluation of architectural schemes. It was concluded that in this case it was also the professional habitus of the actors that enabled the tectonic practice. The use of digital design tools and design tools in general was, however, more pronounced due to the ability to evaluate the acoustical quality of the architectural schemes earlier in the process. It was also concluded that the digital design tools enabled a larger degree of communication between the professionals; the architects' design tools produced digital models and polystyrene models that the acousticians could evaluate acoustically. In this tectonic practice, the new and improved evaluation tools of the acousticians supported the design development well because they enabled an early evaluation of the architectural schemes.

Conclusively, the role of the actor in the tectonic practice cannot be understated. The tectonic practice is a complex process involving many professional specialisations. The ability to support such a tectonic practice

does not only depend on the proficiency of an individual in his or her own field. Furthermore, it depends on a mutual understanding of the aim of the project at hand between the actors, an openness towards the approach of the other professions professional and experience or professional habitus to navigate in the shared space between the professional fields. It could be said that it is not only the depth of an actor's professional knowledge, but also the width to which one can apply this knowledge that enables the tectonic practice. If the actor does not understand what tectonics is or does not have a professional habitus that supports the given tectonic practice, no tectonic practice is going to occur regardless of the design tools available. The computer programmes for computing, geometrical manipulation and visualisation can, however, serve as extensions of the actor's professional abilities. Furthermore it can enable communication between the professionals. While they cannot in themselves enable a tectonic practice, the digital design tools can assist the actors in their quest. To which degree the contemporary digital architectural and acoustical tools do support the various tectonic practices, then, is the subject of the final conclusion.

THE IMPACT OF DIGITAL DESIGN TOOLS ON THE TECTONIC PRACTICES


Answering the auxiliary questions circumscribes the answer to the main research question. In the following, then, the main research question is answered. As it was concluded, what supports and obstructs a tectonic practice depends on the relation between technology and architectural approach. As such, the models in chapter 4 (see page 89) each describe a tectonic practice. While the development of a new architectural approach with a new technology depends on an ability of the actors to work in the shared field between the professions, the development of a traditional architectural approach with a new technology relies less on the ability to work in the shared field.

The adequateness of digital design tools in the various tectonic practices can therefore be discussed in terms of the ability to address the shared field between the professionals, the design tool as ready-to-hand in the right design stage as well its ability to work with new or traditional technology and architectural approach.

Therefore, the answer to the research question of the degree to which the introduction of computer programmes for computing, geometrical manipulation and visualisation enables a tectonic practice is answered in connection to the four relations between the architectural approach and technology.

Tectonic practices with traditional technologies supported by the development of digital tools

Traditional technology  traditional architectural approach

Traditional technology  new architectural approach

Tectonic practices using traditional technologies were not studied as cases, and nothing decisive can therefore be said about the crucial stages supporting these tectonic practices. Something can, however, be said about the design tools that might support this practice overall.

Because the technological (acoustic) starting point would be the classic auditoria, such practices could begin from a precise size and description of the classic auditorium that has served as the main source of inspiration in a given example. In the Opera Theatre case Arup Acoustics issued a guide to the creation of opera theatres. Such a guide could be an excellent starting point for a tectonic practice where the technology used is traditional.

The introduction of acoustic computer programmes would also quite easily be able to support the design development of auditoria that are inspired by the classic hall. This is evident from the development of digital design tools that has already taken place. Some of the acoustic design programmes have been developed (Faist et al, 1997; Felmban and Oldham, 2003) to enable architects to work with acoustics - design tools, which are thereby positioned between the professional fields. It would be well within the capabilities of these design tools to support the two kinds of tectonic practices that begin with a traditional technology because they take their starting point in a well tested prototypical auditorium solution. While both of these examples work from the shoebox-shaped hall, programmes working from a wider array of prototypical auditorium solutions (see page 136) could be imagined. Thereby, these design tools would be close to what Leach (2004) argues is the future of the digital tectonics; using the computer as an effective search machine for acoustic solutions, thereby finding the prototypical solution that is most appropriate to solve a given (traditional or new) architectural approach.

Likewise, these practices can be supported by digital tools in the evaluation stage in order to evaluate any minor changes to the prototype. The close collaboration between the actors is supported by the use of digital tools by both professions, as it was seen in the Opera Theatre case. The architects' use of computer programmes for visualisation and geometrical manipulation produces digital information that can easily be transferred to the consultants' computer design tools.

In the first two kinds of tectonic practices, the introduction of the computer as a design tool can, to a large degree, enable the creation of tectonics. It is also in these two practices that Leach with his manifest on digital tectonics positions the contemporary understanding of tectonics. While it would still be the actors who would enable the tectonic practices, the tectonic practices working from traditional technologies can and will increasingly be possible to support by the development of digital design tools.

Tectonic practices with new technologies on the way to become supported by digital tools

New technology  traditional architectural approach

As the Opera Theatre case showed, this kind of tectonic practice relies primarily on support during the evaluation stage and the translation of the findings by the acousticians to the architects.

In this context the development of the acoustician's evaluation tool is a great benefit. The acoustic evaluation tool in the sixties was the slow and costly method of large scale model testing. While it was ready-to-hand in the evaluation stage of the design, it was not until the architectural scheme was fully developed that it was possible to use. In comparison, the acoustic evaluation by digital simulation programmes signifi-

cantly cuts down the time and the costs of testing various design concepts from the sixties to the present. The ease of evaluating architectural schemes has improved greatly with the advances of the computer programmes. The digitalisation of the acoustic evaluation tools can have (and had in the case studied) the effect that the architectural schemes are evaluated more often. Scale model testing was used only once in the Minor Hall in comparison to the 9-10 times acoustic evaluation by digital simulation was used in the Opera Theatre case. Another advantage of the digitalisation of the acoustician's evaluation tool is that the architectural schemes can be evaluated earlier in the design process. The cost and inconvenience of the large scale models had the effect that the architectural scheme had to be quite developed before it was evaluated through scale model testing. In comparison, the digitalisation of the evaluation has signified that the architectural schemes can be tested at an earlier stage of the design development before it is fully developed. While the acoustician's scale model testing was ready-to-hand in the sixties, the digital tools today are ready-to-hand much earlier in the process.

Despite these improvements of the acoustical tools, the digital evaluation tools that were used in the case did display a weakness. The simulation programmes needed to be complemented by cruder tools in order for the acousticians to work in the very early schemes of the design. To compensate for this in the Opera Theatre case, Arup Acoustics supplement the digital evaluation with polystyrene model evaluation. The use of polystyrene models in the Opera Theatre case, therefore, points to a continuing challenge to the evaluation tools used by acousticians. The inability of current acoustical simulation tools to support the evaluation of the early architectural schemes has also been argued by a number of authors (Felmban and Oldham, 2003; Schmidt and Kirkegaard, 2005; Zhang, 2005). Even though digital acoustic programmes (such as CATT and Odeon) have improved in terms of their ability to evaluate early schemes, they are still un-ready-to-hand in evaluating the first, crude schemes drawn up by the architects.

The computer programmes that actually do address this first evaluation (for instance the architectural acoustic teaching software described by Turner and Barnett (1998)) were not used in the case. In general these programmes would not likely to be used when the architectural approach is traditional because the aim of the programmes is to enable the architect to evaluate the acoustic quality of the first crude sketches in order to develop the architectural scheme from acoustic considerations. The design tools that best supports this approach is, as argued in the case study, tools that support each profession within their own field.

However, the development of the acoustician's simulation tools will in the coming years probably address the problem of evaluating early sketches since there is already a clear tendency towards earlier and earlier acoustic testing of architectural schemes.

Likewise, the use of digital design tools by architects has a positive effect on this kind of practice. The architectural tools for visualisation and geometrical manipulation have increased the ability to communicate the architectural schemes accurately and rapidly to the acousticians. This communication between the professionals has increased the evaluation of the acoustic quality of the schemes. In the Opera Theatre case, the improved communication between the professionals could be seen in the transfer of digital models as well

as in the fabrication of polystyrene models from the architectural design tools.

Conclusively, the kind of tectonic practice that aims at developing a traditional architectural approach with a new technology has to a large degree been enabled by the digitalisation of the architects and acousticians tools. As in the other practices the actors are the primary enablers but the practice is supported by the digital tools. The manner in which the ability to conduct this tectonic practice could be improved even further would be by improving the ability of the tools used by acousticians to address the evaluation of even earlier architectural schemes while enabling the architect to evaluate acoustic quality on his own is less likely to have an effect on this approach.

New technology \longleftrightarrow new architectural approach

Lastly, the case studies showed that the tectonic practice that aims at developing a new architectural approach with a new technology relies primarily on support in the analysis stage in order to develop the design from an understanding of acoustics. While the introduction of the computer is an improvement to this kind of practice similar to the other practices, the computer programmes have, however, major shortcomings in connection with this kind of tectonic practice.

The first shortcoming is that the main evaluation design tools (such as CATT and Odeon) are still in the hands of the acousticians, and that they are too complex and detailed for the architect to use. Likewise, the architect's design tools have grown in complexity, and while the pencil sketch is easily accessible, the computer design tools for geometrical manipulation and visualisation are specialist design tools most often used solely by architects. The manner that computerized design tools are used in the Opera Theatre case and in many other architectural projects can therefore be said to reinforce the division between the professions, rather than becoming a shared tool between the professional fields.

There are some acoustic evaluation tools, however, that is intended for the architects to use. The one suggested by Felmban and Oldham (2003) fail in this approach because they begin from a traditional technological outset. The one suggested by Turner and Barnett, however, maintains an openness towards the design development and is intended to be positioned between the professional fields.

Acoustic quality depends on a number of aspects such as the volume of the auditorium, the shape of the enclosing surfaces as well as the materials of the surfaces. All the aspects interact and therefore acoustic evaluation programmes such as CATT and Odeon attempt to evaluate all the parameters together. Contrary to this, the programmes described by Turner and Barnett are characterized by beginning with exploring only one aspect - the shape of the enclosing surfaces and only secondarily refining the evaluation into encompassing the materials of the surfaces and the volume – much like the working method of Jørn Utzon in the Minor Hall case.

From an architectural point of view, these programmes hold a great potential because they break down the complexity of the acoustic evaluation and deal with the acoustic rules of thumb as manageable parameters. However, from an acoustic point of view the reluctance towards such programmes is understandable

because they only deal with part of the complex entity of acoustic quality. This contradiction between the design tools being ready-to-hand for the architects to use early in the process while not being accurate enough to deal with the full complexity calls for the continuing involvement of talented actors.

The design tools that Turner and Barnett develop can support a tectonic practice with new technology and architectural approach because they support the design development from acoustic considerations. The limitations of the programmes should, however, be realized and compensated for – not by developing the tools into complex programmes but by involving acousticians who can explain the limitations and further develop the designs with more sophisticated acoustic considerations.

The second shortcoming of the digital tools in supporting this tectonic practices is that the acoustical design tools have the same characteristics in connection with the design process today as in the sixties, thus supporting the evaluation stage and not the stage that is crucial to this kind of tectonic practice; the analysis stage. This applies to the programmes used in the case study as well as the ones developed by Turner and Barnett (1998). Scale model testing as well as the digital tools were, as such, ready-to-hand design tools in the evaluation stage of the design process, and even though the digital tools have become easier and quicker to use, they address the same stage of the design process.

Even the acoustic tools developed by and for architects focus on evaluating the architectural schemes with respect to acoustics rather than developing architectural schemes from acoustic concerns. The programmes evaluate the geometry of an architectural scheme in a separate acoustic programme which, from a tectonic point of view, is unfortunate because it separates the acoustic concerns from the development of form. Rather than separating the concerns, the acoustic programmes might in the future become interactive and enable a development of form in close connection to the acoustic evaluation. This calls for programmes where geometry can be created as well as evaluated acoustically in one and the same digital environment.

Conclusively, in connection with acoustics this kind of tectonic practice has not been revolutionised by the introduction of the digital design tools. The digital tools have two major shortcomings in connection to this practice: they are either too simplistic to capture the complexity of acoustic quality or too complex to be used by architects, and the design tools support the evaluation stage instead of the analysis stage. While the digital tools can support this practice to a certain degree by enabling an early evaluation and development of form from some acoustic aspects, the practice is still dependent on actors with a full understanding of the complexity of acoustic as well as architectural concerns.

SUMMARY OF FINDINGS

The findings from the preceding analysis of the tectonic practices and the support of digital design tools can be summarised as follows:

- The use of design tools can never fully enable or obstruct a tectonic practice. The tectonic practice cannot be fully enabled by the design tools because the individual actors using the tools have to do so with a tectonic result as the aim. The tectonic practice cannot be fully obstructed by the design tools because the individual actor can supplement the available tools by ready-to-hand design tools depending on the practice.
- The introduction of the computer's ability to compute, geometrically manipulate and visualise does support all four relations between technology and architectural expression used to understand the tectonic practices. The degree to which the introduction of the computer as a design tool has had a decisive impact varies, however, between the tectonic practices.
- The introduction of the computer's abilities to compute, geometrically manipulate and visualise enables to a large degree tectonic practices that draw upon a traditional technology. Computer programmes for design development of auditoria from the classic auditoria have already been developed. Likewise, a generative approach to auditorium design as Leach (2004) envisions it would support these practices.
- The introduction of the computer's abilities to compute, geometrically manipulate and visualise enables to a large degree a tectonic practice that aims at developing a traditional architectural approach with a new technology. The communication based on the compatibility of the architect's and acoustician's digital tools supports this practice, as do the evaluation tools of the acoustician. Facilitating an even earlier support of the acoustic quality by digital tools (for instance by merging the acoustic tools developed by architects into the acoustician's simulation tools) would support this practice further.
- The introduction of the computer's abilities to compute, geometrically manipulate and visualise has to some degree enabled a tectonic practice that aims at developing a new architectural approach with a new technology. The ability for architects to work with simple acoustic programmes and digitally develop the architectural form supports this tectonic practice but also necessitates the involvement of acousticians to capture the full complexity of acoustic quality. The digital design tools can not yet support the development of new architectural form from fundamental acoustic principles. This part of the tectonic practice could be supported by interactive programmes where the development of architectural form and the evaluation of acoustic quality could be closely intertwined.

VALIDITY

Internal validity

To Validate Is to Question (Kvale, 1989).

Internal validity fundamentally means to ensure that what is studied actually sheds light on what it is intended to investigate, and this aspect of validity can therefore be discussed by comparing the research question to the knowledge produced. It could be said that where the methodology chapter is the attempt to

foresee the steps necessary to answer the question, the validity is looking back on the project (either through the project or as here in a discussion) and attempting to ascertain whether the steps worked as intended. The research question guiding this research was,

To which degree does the introduction of computer programmes for computing, geometrical manipulation and visualisation into the collaboration between architects and consultants enable a tectonic practice?

In this research question an important point is the introduction of the computer programmes. Therefore, the method attempted to design the research in a manner that favoured the study of the introduction of the computer programmes. The methodological take was to do a comparative study of a case study in the pre-digital era where the computer was not yet introduced and a case study in the digital era where the computer was used. The projects studied as cases were chosen in order to be as similar in their tectonic practice as possible – it would thus be possible to compare the design tools' effect on this practice. The Minor Hall project compared to the refurbishment project of the same hall thus seemed ideal for the purpose. With Jørn Utzon involved in both projects, it was expected that the tectonic practice would be quite similar. As in most case studies, however, the reality was more complex than what was expected from behind the desk in the research office. The architects in the Opera Theatre case did not conduct the same tectonic practice as Jørn Utzon did in the sixties. Instead of developing a new auditorium prototype, the architectural team was clearly (and understandably) inspired by the original Minor Hall. It was expected that the Opera Theatre case would be an example of a new technology and a new architectural approach, as was the Minor Hall, but this was not the case. The methodological step to research two Utzon-cases was taken to ensure two comparable tectonic practices. The cases, however, represented quite different tectonic practices.

This was a cross-road in the research. Compared to the pilot cases (see the methodology chapter for further discussion), it was clear that cases with such clear tectonic intentions were hard to come across. In addition, both cases were great sources of knowledge about tectonic practice. It was therefore decided to pursue the cases. It was clear, however, that what was studied was no longer the tectonic practice but two kinds of tectonic practice.

With this realisation, the design tools in the two cases could no longer be compared directly, and an extra step had to be added to the methodology. It was necessary to discuss the two cases as examples of two distinct practices, discuss how these practices manifest themselves in the design stages, and subsequently discuss how the digital design tools could support the practices. The cases could still be used to compare the development of the design tools of the architects and acousticians in the pre-digital and digital eras. It was, however, necessary to consult other sources to describe other available design tools since the ones used in a case should now be understood as the ones supporting that tectonic practice, and not a tectonic practice in general.

Along the way, this change of the methodology has developed from being a necessity to actually broadening the research. Instead of learning about only one tectonic practice, the understanding of the tectonic

practice has been unfolded to encompass four different kinds, including how they are supported by actors and design tools. The relationship between which kind of tectonic practice is undertaken and how these are (and should be) supported differently by actors and design tools is, as such, perceived as the most important finding of this research.

External validity

External validity, as opposed to internal validity, is concerned with whether the knowledge produced is applicable to the world at large (Kvale, 1989), i.e. if one can expect to find confirmation of the research results in the outside world, the knowledge is externally valid. In this case, the question is whether the knowledge produced about the ability of the computer in relation to tectonic practices is only applicable to exactly the projects studied, or whether it can be generalised to other architectural projects.

Is it valid to generalise a tectonic practice by only studying one example of each? From a classical scientific view (both in social science and natural science) it is not. Recent research has, however, indicated that a well selected case often has more knowledge to offer than large quantities of cases. The use of one case representing a tectonic practice is based on what Flyvbjerg calls the force of example.

“One can often generalize on the basis of a single case, and the case study may be central to scientific development via generalization as supplement or alternative to other methods. But formal generalization is overvalued as a source of scientific development, whereas “the force of example” is underestimated.” (Flyvbjerg, 2006, p. 228).

The cases are illustrative examples of how the appropriateness of design tools and the actor’s professional habitus depends on the tectonic practice.

The knowledge produced cannot be said to be valid to all architectural practices - only to tectonic practices, and even so, only to tectonic practices that are involved with developing tectonics in the Building Principle approach. As such, the knowledge produced here cannot be generalised to tectonic practices concerned with Materiality and Technique or Component and Composition without further studies.

A future research area that would be interesting to investigate is whether the introduction of digital tools has had a significant impact on the tectonic practice within the other tectonic approaches. While the conclusion regarding the ability of digital tools to support a tectonic practice in the Building Principle approach, a research project uncovering whether this is also the case in the approach of Materiality and Technique as well as the Component and Composition would be interesting. Likewise, it could be interesting to investigate the collaboration between other consultant fields and architecture. It is expected that the findings regarding how actors and design tools support a tectonic practice can be generalised from the field of acoustics to other consultant fields such as structural engineering and indoor climate, but to verify this assumption, it would be necessary to conduct comparable studies in these fields.

It is therefore maintained that the findings may be generalised to apply to tectonic practices concerned with

Building Principles, the distinction between tectonic practices, the stages in which such practices differ, and how such practices can be supported by actors and design tools.

IMPLICATIONS

Contribution to the research field

This research, then, contributes to the field of tectonics by developing an understanding of tectonics as a practice that can be supported by design tools. The understanding of tectonics as a built edifice, which is advanced by numerous authors (among them Sekler, 1965 and Frampton, 1995), is supplemented by an understanding of tectonics as a practice. The two understandings of tectonics are mutually dependent: the actors need to understand this quality of architecture in order to strive for it in their projects. At the same time, a broader understanding of the tectonic practice can facilitate the creation of tectonics in a contemporary context, for instance by expanding the vocabulary that architects can use to describe and discuss the practice, the organisation of project teams and the degree of renewal in the project at hand.

The ability to create tectonics in this conception of the tectonic practice is transformed from being understood as the work of one talented architect to being a collaborative effort of the talented architect, the talented acoustician as well as an inspired use of design tools.

The research also contributes to the field of digital tectonics. The findings support Leach (2004) in the claim that it is not solely the ability to evaluate technical concerns or develop architectural form that is significant in the tectonic practice. Rather, it is the ability of computer programmes to support the development of architecture where the technical principles are inherently addressed by the architectural form.

The findings in this research, however, call for less confidence in the digital design tools than the field of digital tectonics does. The research unfolds the understanding of how design tools can support a tectonic practice, but the findings stress how the individual actor and the tectonic intention should not be underestimated in the tectonic practice. Likewise, the research concludes that most of the contemporary digital tools have developed the practitioners' ability to work with areas of the profession that they already did well in a pre-digital era. The contemporary digital design tools are not yet developed in the areas that were difficult back then as well; for instance in acoustics they do not enable the architect to work with acoustics.

In addition, the understanding of how digital tools can support a tectonic practice is nuanced by introducing the distinction between various tectonic practices. When Leach perceives generative programmes such as eiffForm to be promising to the future of tectonics, it is the formative stage of a tectonic practice with a new architectural approach, but a traditional technological core that he is addressing. It is a new array of design tools – still not developed in the field of acoustics that would be necessary to develop tectonic architecture with a new technological substance. The research findings thus indicate that in order for the digital tools to be able to address tectonics, all kinds of tectonic practices should be included in the development of digital tools.

Implications

Contemporary applications of digital design tools are transforming the way tectonics is being practiced. The dissertation has attempted to address issues that may further an understanding of the degree to which the tectonic practice can be supported by design tools. More specifically, it has focused on the tectonic approach called Building Principles, where the spatial organisation of architecture is influenced by structural, environmental, acoustic or similar principles. The case study research focused on the collaboration between the acoustician and the architect and demonstrated how the tectonic practice is characterised by the relation between the architectural approach and technology.

It was concluded that the degree to which the current digital design tools enable a tectonic practice varies depending on the tectonic practice aimed at. As such, digital tools offer a great deal of support in connection with the use of traditional technology by enabling the practitioners to work proficiently with their own professional field as well as it increases the ability to communicate between the professional fields. In connection with the use of new technology, however, the digital tools can still be developed in ways that would support these tectonic practices better.

The primary implication of the study is that tectonics can be understood as a quality of a practice as well as a quality of the built architecture. The future of the tectonic practice is not to re-establish the architect's status as a master-builder. Instead, it lies in the realisation that the professional specialisation is not a contradiction to the tectonic practice – only a condition meaning that tectonics needs to be practiced in another manner. This realisation is not only important for the practitioners but at all levels; theoretically, strategically and politically.

Tectonics can be practiced outside of the master-builder era, and the end of this era should not be understood as the end of tectonics. What will be an end to the tectonic practice, however, is a lack of methods and design tools for collaborating with tectonics as the aim.

A main implication of this study, then, is that in order for the future design tools to support the development of tectonic architecture, it should address the contemporary practice situation of tectonics as a collaborative endeavour. As it stands today, digital tools are primarily developed to support the professions within their own field. In connection with acoustics some of the rare attempts to create an acoustic design tool for the shared field between the professions have failed because the programmers did not understand the architectural design process well enough (Felmban and Oldham, 2003) while others are developed from an intimate understanding of the architectural design process but are simplified in order to render them ready-to-hand in the first stages of the design process (Turner and Barnett, 1998). To support a future of the tectonic practice that develops architectural expressions from a new technological substance instead of only solving new architectural expressions structurally, acoustically and environmentally, a development of these shared digital design tools is imperative. The talented and visionary practitioner can create tectonics regardless of the available design tools. However, the continuation of the tectonic tradition in a contemporary context (that is increasingly dependent on digital technologies) may well rely on the continuing development of digital tools to support the tectonic practices.

The design tools cannot fully obstruct or enable a tectonic practice, and the actors are, as such, still central to the tectonic practices. The future of the tectonic practice depends on the practitioners' tectonic intentions and the eager to actively engage in the difficult task of understanding and using the knowledge of other professional fields in their design. The aim is worth striving for – a rich and diverse built environment maintaining an architectural tradition of material and tactile quality, an ability to absorb new technology into the built environment and a new economic argument for architecture as a full scale laboratory in which knowledge and technology are developed.

APPENDIX

[illegible][illegible][illegible]

[illegible]

| | | |
|--|--|--|
| | | |
|--|--|--|

© 2006 The Authors

[illegible]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

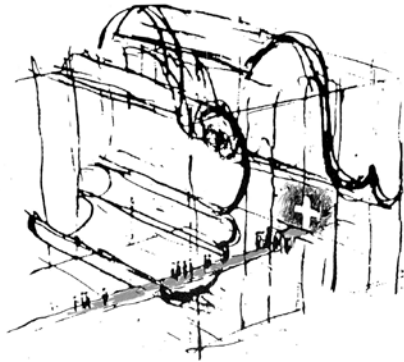
[REDACTED]

[REDACTED]

[REDACTED]

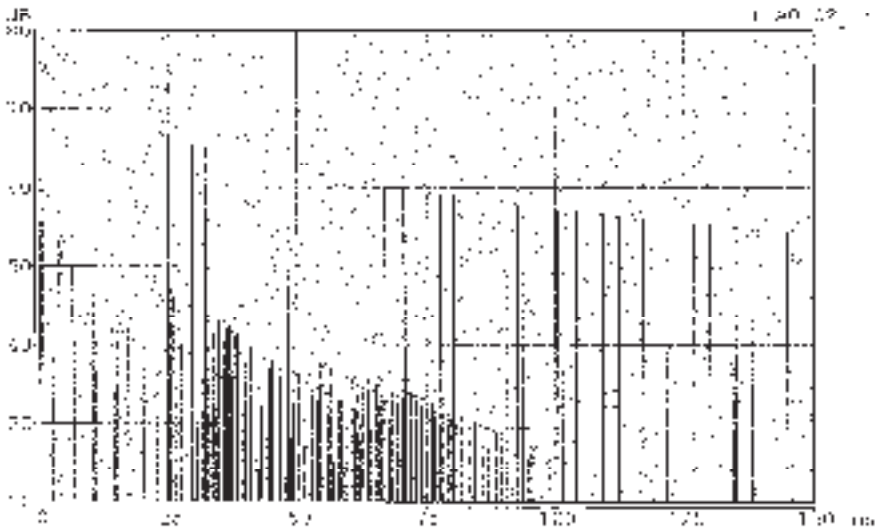
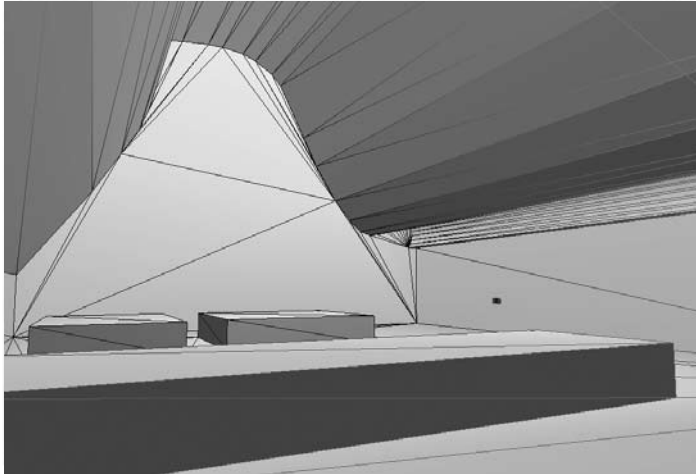
[REDACTED]

[REDACTED]



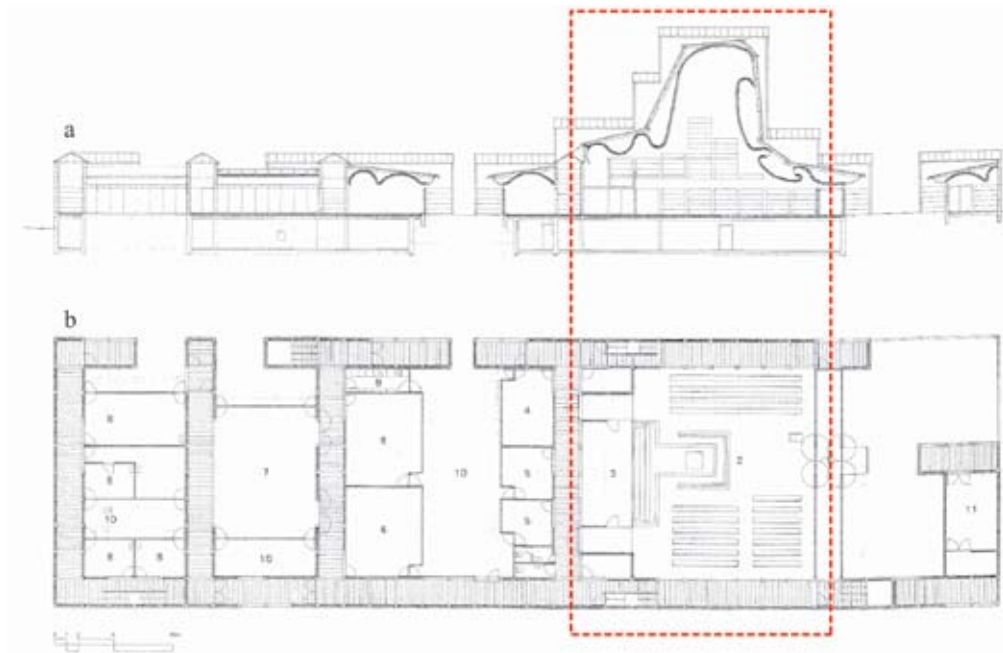
[REDACTED]

[REDACTED]



[REDACTED]

[REDACTED]

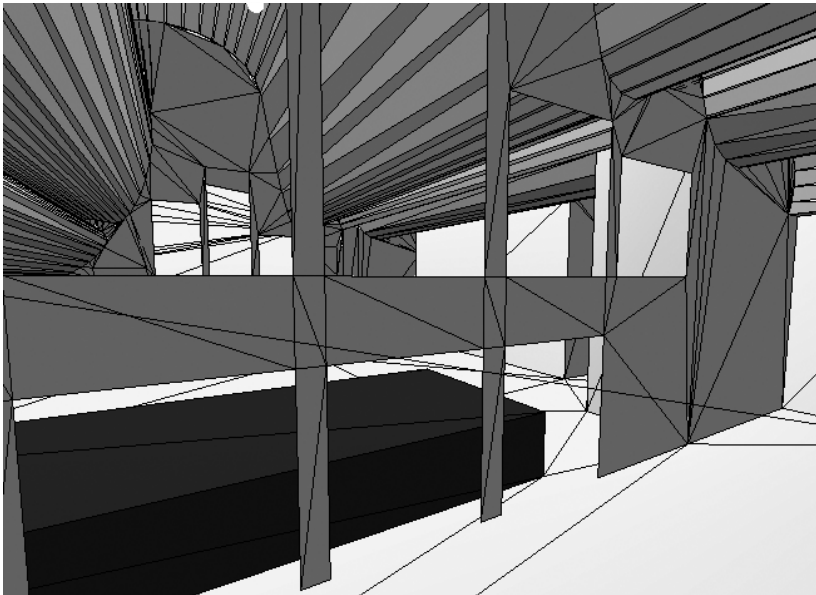


Bagsvaerd Church. The acoustical room in question is indicated.

[REDACTED]

[REDACTED]

[REDACTED]



[REDACTED]

[REDACTED]

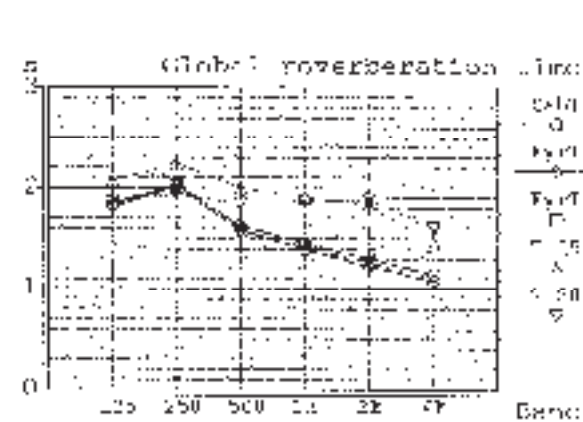
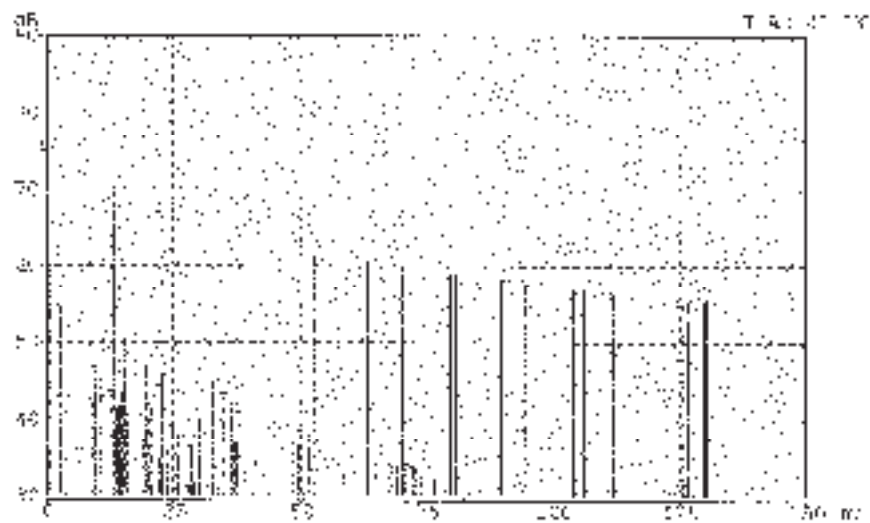
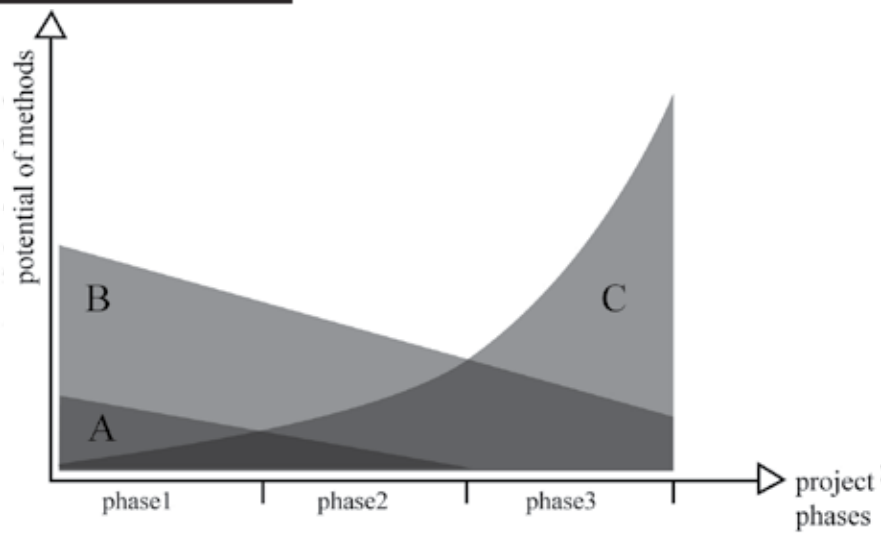


Figure 8. Reverberation curve

Figure 9. Data list for geometry Figure 5.

[REDACTED]

[REDACTED]



[REDACTED]

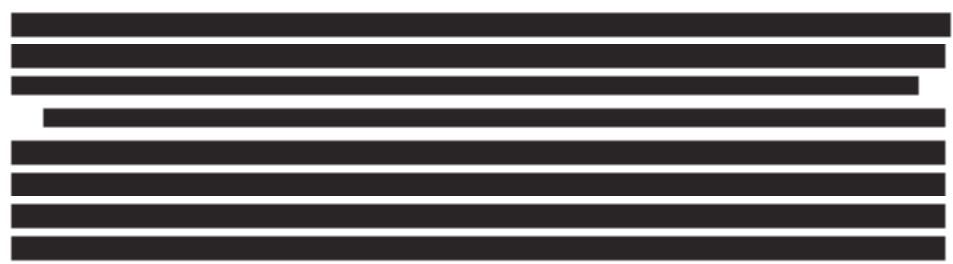
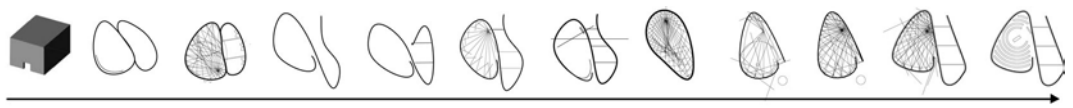
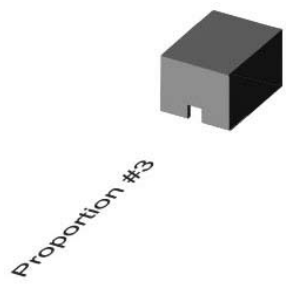
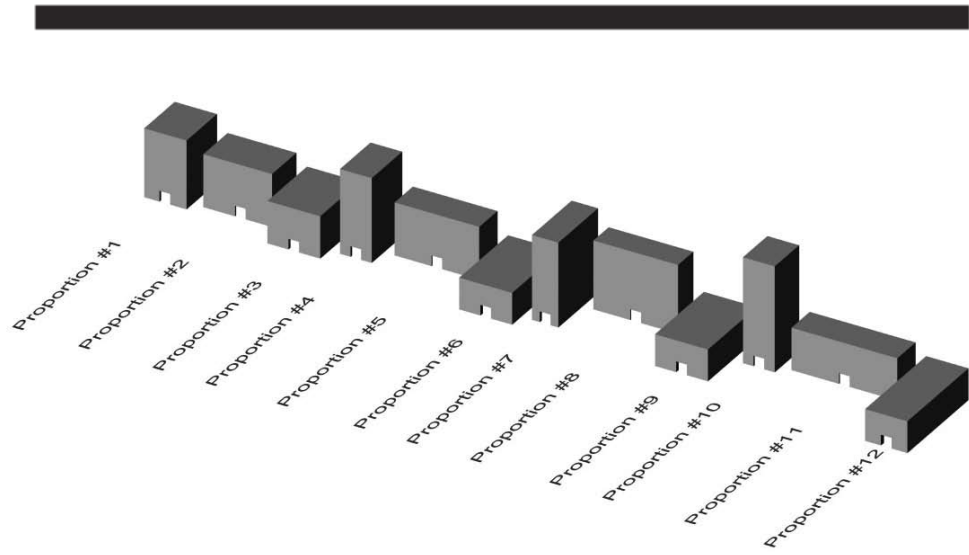
[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]



[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

INTERVIEWS

Richard Johnson [A] - February 15 2005
Richard Johnson [B] - March 02 2005
Richard Johnson [C] - July 21 2005

Matt Morel - February 22 2005

Jan Utzon - April 26 2006

Andrew Nicol [A] - April 05 2005
Andrew Nicol [B] - April 26 2005
Andrew Nicol [C] - June 28 2005

Niels Jordan - November 24 2004

Norman Gillespie - May 5 2005

Gregg McTaggart - March 22 2005

Joseph Skrzynski - February 3 2005

| | |
|--|-----|
| Interviewee: Richard Johnson, Director Johnson Pilton Walker [A] | |
| Interviewer: Anne Marie Due Schmidt | |
| Date: February 15 2005 | |
| 5 Location: Meeting room at Johnson Pilton Walker, Sydney Office | |
| Notes: Matt Morel, the project architect of the Sydney Opera House project, was present during the major part of the interview. | |
| 10 | |
| AMDS: What I am doing in my PhD study is regarding tectonic design, about how the technical matters in architecture how they can work together and not against | |
| 15 each other... | |
| RJ: Yes | |
| AMDS: ... and one of my cases is the recent development of the Opera House that you have been working on with Utzon. And one of the things I am focusing on is acoustics because | |
| 20 I think it is very interesting also because it is actually a field where the human experience is translated into something technical and then by architecture being translated into a human experience again. So that is what I am looking into. | |
| RJ: If you could just stop there for a minute, I'll get my | |
| 25 colleague I think he should hear this because if I am not here, he'll be the one you should talk to. | |
| [...Matt comes in and it is explained again] | |
| 30 AMDS: So, what I would like to ask you about first is a bit on the background of the project that you have been working on. I have heard about how you worked with Utzon and tried to understand how he is working to translate that into the new project. But how did it all come about and when did it | |
| 35 start and how did it start? | |
| RJ: It was around six years ago, when there was a wish on the part of the Opera House Trust to change the future of the building. Clearly, the building had had | |
| 40 25 years of operations and had exceeded everybody's wildest expectations with, I guess, its iconic character, its importance in the cultural life, the city ... all of the symbolic, cultural, aspirational aspects of the project was way beyond everybody's dreams. So on the one hand you had probably | |
| 45 the greatest piece of architecture or symbol or place of the 20th century and on the other hand you had a building that functionally was so inadequate that it was fast approaching | |
| obsolescence. It was being held together by the dedication of a whole range of people who continued to make it work | |
| 50 behind the scenes through human effort and money. And whilst other major theatres or auditoriums in the world even built later than the Opera House had undergone | |
| major refurbishment, this one hadn't. Utzon himself acknowledges that had it been built and completed with | |
| 55 the auditoria that he had planned, it would now still need adjustments. | |
| AMDS: Yes, after 25 years! | |
| RJ: And there's a whole range of new technical | |
| requirements, standards etc. But I think the important thing, ...there was this sense because of the iconic | 60 |
| nature of the building, that one shouldn't do anything. That everything was important. There was a Conservation | |
| Management Plan that was trying to guide the future of the building as a heritage building, which effectively said | |
| that everything is important. It did not have the benefit of | 65 |
| the discussion. So what tended to happen was that when a problem was identified and a range of possibilities was | |
| examined, it was the Heritage Legislation that prevented | |
| anything from happening. | |
| AMDS: All right, so they just froze everything. | |
| RJ: There was a sense that it would be too hard to change | 70 |
| anything, there was the Legislation saying that this important, so we can't change anything. And I think equally, | |
| in this city at least, there hadn't been much architectural | |
| discussion about the significance of the work, or about | 75 |
| Utzon's work in general. It is only very recently. There have been a number of attempts to write books and the best | |
| of them, I think, is Francoise Fromonot, but it did not have | |
| the benefit of talking to Utzon. Prior to that I think it was | |
| generally people who had a passion for the soap opera | |
| of the sagging of Utzon. The focus was on the process, | 80 |
| not the product. And there has not been any architectural | |
| debate in the universities or internationally. The archive, | |
| the Utzon archive exists in this town in the library and you | |
| can check the list of people who went there and consulted | |
| it, almost none did. So in a sense, nobody knew what they | 85 |
| were doing. The Trust couldn't move forward to turn it into | |
| a functional performance arts centre of significance. They | |
| wanted to re-engage with Utzon and the Olympics were | |
| approaching, federal money was going to be just around | |
| the corner and we'd better have a plan so that before the | 90 |
| money came we would know what to do. The government | |
| did a plan that was controversial and invited architects to | |
| send in proposals to implement the plan and we went and | |
| expressed an interest in throwing away the plan - and we | |
| got the job. So we said, we'd be interested in connecting | 95 |
| back with Utzon. How we are going to do that, we had no | |
| idea, but we must get back to Utzon's core ideas that is | |
| driving this whole building and giving it its key significance. | |
| We must go back to rewrite the conservation plan, we | |
| must look for what core that should lead the next 25 years. | 100 |
| And that has taken a lot of time. All of these things are | |
| really happening, Utzon is now engaged and has written a | |
| document called The Design Principles... | |
| AMDS: oh yes, I have read them | |
| RJ: ...and he has been involved with us in writing a Strategic | 105 |
| Building Plan to accomodate the needs for the next 25 | |
| years. From that was identified a number of projects of | |
| which the Opera Theatre was one of them. So that's the | |
| broad context. | |
| AMDS: yep | 110 |
| RJ: And I think a lot of the during for the Opera Theatre itself | |
| came from the earlier project to fix the playing conditions | |
| for the orchestra in the pit. | |
| AMDS: Alright | |

- 115 RJ: And from that came the realisation that to close the building down for.. how long was it?
Matt: 18 months
RJ: Then you're enabling the orchestra to hear themselves playing better, but there is no change to the auditorium, it's still a blackened out. And the acoustic are worse for the audience, then the people might be upset. So the Government asked, through us, Utzon to consider 'what else could you do?' And for some time he considered turning it from the black auditorium - this is the existing auditorium, not his one - turning it from the black into a colourful culmination of the journey of experience. Till he got to a point of realising that that was not going to work, basically the set of shapes... he considered repainting the existing auditorium.
- 120 AMDS: And that just wasn't enough, or?
RJ: No, what it would do was to expose the fact that the geometry was terribly inappropriate and not enhancing his geometry, so he then end up saying that 'no you shouldn't do that'. And from that grew the benchmark study of the acoustics; looking in greater depth at what are the issues of that particular auditorium. That then lead, inevitably, to trigger to say, well we need to double the mass and...did we need to double the volume?
Matt: we needed in the area of 50% more volume.
- 130 RJ: there were air conditioning problems, there was disabled access problems, there was a lot of stage problems and fire issues. And if you attempted to satisfy those serious functional deficiencies in isolation then, inevitably, you'd spend a lot of money and still not have an auditorium that was compromised. So more study was done and we are in the middle of a study now, with Utzon, to redesign the whole theatre. And it's beginning to look very promising. So that's the story brought back to you.
AMDS: Yes
- 140 RJ: I think... a number of projects has been stocked so that we know what his intentions are in quite detail so that in the future when spaces needs to get changed we know what he'd do. Sometimes we have drawings and sometimes we have descriptions; we also have a document called Utzon on Tour where Jan and I walked around the building with a videocamera and then he spoke - he was not there, Jan took it back to him - and Jørn spoke to it, describing his reactions to it and what was consistent with his ideas and what was not and what should happen do this place. So we have quite some documentation of his vision of what should happen in the future. And... have you seen the Utzon room yet?
AMDS: No, I haven't. I have a number for somebody who is going to arrange it...
- 150 RJ: .. Chan?
AMDS: No, Ralph Bott, a protocol officer
RJ: Ok, I don't know him.
AMDS: No, I don't know him either
RJ: All right, so that northeastern foyer's starting to implement new designs of the interiors and when you see this - it's not a huge project - but it is clear enough compared to what was there before to show people what is possible with the interiors with Utzon's sense of materiality and his sense of human experience.
- 175 AMDS: Now you've given me an account of how the project started but how did you then get to meet Utzon and get him convinced to get involved? Was it you or Joseph [Schrynski] who convinced him?
RJ: I don't know, I wrote him a letter and he responded. And I had a letter from the Premier to take. I don't know how to answer that question you'd have to ask him - but he's back.
AMDS: Yes.
RJ: I think the answer is that there is never a simple answer to anything. What matters is that he's back. And we enhance this opportunity that we've got.
- 180 AMDS: But it must be difficult to work in this in-between situation. I mean, of course you are an architect and you have your own identity and now you are working as a kind of medium for Utzon.
RJ: It is not difficult at all, it is fantastic!
I think the building has such a strong identity and presence and Utzon has got such profound and strong and simple ideas. Once you begin to understand, once he opens the door to allow you to understand, the building itself will talk to you. He doesn't tell you everything, he sometimes waits for you to find things. Sometimes he even doesn't know what to tell you. So frequently we have tried to solve a known problem and then we see the original drawings, and there is a subtlety in the way they are drawn that tells you something that you didn't see before. I think the Opera Theatre is interesting because there is such a strong conceptual direction. It wasn't an idea that he was isolating from the interior, the acoustical considerations, the constructability, the family of organic shapes or the geometric order. He encompassed all those within one idea. What surprises me I think is that nobody has tried to build an auditorium like this. These ideas have been around for forty years! There is not a single auditorium.
AMDS: That has used those ideas, no.
- 190 RJ: Somebody must have tried it. The acousticians initially said 'no, no, it's not going to work!' but it does work! And they are saying that as well. I think they are used to looking at things - to interrogate early proposals - in section and imagining that section extruded that way [along the full width of the building] in a similar section. And even when you draw or make a model it's difficult for them to actually understand - I think. Not that... they can see it but it's a question of does their experience tell them that will work acoustically. A lot of the acoustic modelling that has been done has validated some of the earlier propositions made. The acoustician was at the Louisiana exhibition and there were the ply-wood models of the ceilings and we were in the middle of it, we were in the early stage, at that time and he was very doubtful of whether the radial geometry was going to work. He was wanting to be helpful, wanting to move forward, wanting them to work but all the time there was doubts and questions. We... we used to vacillate from saying 'ok, let's start again. If you had no constraints,
- 195 185 195 200 205 210 215 220 225

what would you do?' and he couldn't respond. And 'ok, let's work with this idea, why doesn't this work?' It was a moment when he saw the Utzon model that he started to understand that the radial geometry wasn't going to be a problem. I think that was when we really connected and we started to move forward.

AMDS: And who was that?

RJ: This was Rob Harris

AMDS: Ok, in London

RJ: Yes. There were times when having achieved the right... the sort of shape and the sort of volume and it'd fit within the shapes that the engineers and project managers were keen to find a what they thought were a simpler and easier way of doing things 'it surely must be easier,' so we were pursuing, you might say 'visionary ideas' as well as a whole lot of other things, 'surely it must be easier in steel,' 'surely it must be easier in some other material'. And we went all through this process and inevitably ended back with plywood. With everybody agreeing that that's the best way.

AMDS: And why was that, I mean why did the other options fall?

RJ: Because again, it was a holistic solution. It solved within it the acoustic performance issue, the sound isolation issue. It solved the issue of pre-finishing and pre-fabrication, it had to be fast if we had to shut down the auditorium. It solved the issues of access for lighting bridges, it solved [hard and] mechanical exhaust and probably a whole other layer of other things. It was again a holistic idea. And I mean, everything else would have been incredibly clumsy. For example if you built it in steel – because steel you can get in there and built it fast and hook it up there with not much weight – the amount of wood, the ply-wood, that you'd need to then put on to the steel for the acoustic performance was greater than the wood necessary for the structural support. The steel was then redundant. The determinant for the thickness of the plywood was not the structural reasons, what was needed for acoustic reasons were well in excess of what was needed for structure. It was not the acoustic performance from the auditoriums side; it was a matter of sound insulation. And Matt were going there with me and we were trying not to be angry because people were trying very hard to push the design in different directions and you'd ultimately always come back to the same because of the subtleness of the original. But there were many attempts, weren't there [to Matt], to push the project. The beauty of these ideas is that the conceptual approach embodies everything for the making within. There is no adding, no extra. And I think it comes from Utzon being such a critical and pragmatic person 'how big is that piece of plywood, how big did they make it and how thick is it?' Not 'I need a special thickness' or 'can't they do this with it?' He knows the nature of the material.

AMDS: But this project was done with the production in mind that was available at that time. Hasn't the ply-wood changed since then?

RJ: Ply-wood has changed because we can now no longer

get huge lengths of it. The ply-wood manufacturing was more sophisticated in Sydney when he was here, than it is now.

Matt: You can get long lengths of ply-wood, but not within Australia.

RJ: But it's not as determinant acoustically as it was in his time because we can get the structural rigidity in other ways. His view of tectonics, to get back to the subject of your thesis, was saying that in order to distribute evenly out evenly from the stage in a balanced way, and if you look at the way rays bounce off and imagined, theoretically, a good shape to do that [holding his hand in a curved shape to represent the shape of the ceiling] and the same time imagine being in the audience looking and imagining that the shape of the auditorium is helping you to focus on the stage. That the two are the same, that the sound and the eye work together. And I don't think that acousticians and auditoriums built in the past understand that.

AMDS: no

RJ: Even traditional auditoriums, they don't actually focus your eye on the stage. They focus on the stage but by blackening everything out. I think he has this view that sound and acoustics are the same. Acousticians know that too because we were pushing an earlier argument about electro-acoustics and it seemed that before we got to the decision to built a new auditorium that all sorts of opportunities had to be explored to see how much we could improve the current auditorium. And one of the ideas, on behalf of the Trust, was to explore how much could be done with electro-acoustics and the acousticians were dead-against the idea.

AMDS: Yes, there is a huge discussion on it now

RJ: It's a huge discussion. It was their idea that for good experience in auditoria what you hear needs to be acoustically compatible. If you walked into an auditorium and your eye knew that this was a very soft auditorium and there were hardly any hard surfaces and what you heard was then a big reverberant space, it wouldn't be satisfying. The eye and the ear are so well connected. You can marginally fool them, but only with subtle changes. You can not make an auditorium with a reverberation time of 1.1, which is what the current auditorium has, sound like 1.4. So I think there is a really interesting connection between sight and sound. And Utzon intuitively knew.

Of course you've read about the long journey from the city along the harbour, in very natural colours, and then you turned into the hall with the Utzon interiors, which was almost the culmination of the journey. And then the performance started, when the overtures played, the light stayed on, this was his idea. And then they slowly dimmed, this apparently used to be done in the 19th century by some conductors. He had thought about what should happen to the light, how to adjust your eyes, what the purpose of the overture was and how this should be incorporated into the architectural experience. So I think he was, and still is, very aware of this experience.

AMDS: Joseph Skrynzki was telling me about how you got to

know his ideas through the design of some toilets, so I was hoping you'd show the drawings of that at some point.

345 RJ: Yes. I think that the understanding of his principles came through discussions with him, and the design for the toilets were only a minor detail in that understanding. He wasn't interested in doing them....in those days with the early discussions 'no, you do it'. And I think it became for

350 him a curiosity to see what we might do and a bit of a test of course. So it was certainly important but that project was several years ago. We had no funding and ... nothing is simple!

AMDS: But even now the project is not certain, I mean you don't know whether you'll get the funds to actually realise it?

355 RJ: I don't think that is the problem, it'll happen some day. The most important thing is to know what to do. The momentum is there. If the solution is correct, not only

360 giving Utzon an opportunity to do a major component of the interior but in the process solving all of the functional and operational problems that exists. It will happen, it inevitably has to happen. A city that is sitting on the greatest symbol of the 20th century why won't it eventually see that it has to

365 spend some money to maintain it? It would be ridiculous for somebody not to do that. I can imagine somebody not being brave right at this instant but in a ten years time there won't be so much hesitancy. The important thing, I think, is that whilst Utzon is reengaged with the project we get it

370 to a point of reality where there is no doubt of what can be done.

AMDS: And what will happen in the future do you think? Will they attempt to rework all of it? I mean the concert hall is pretty well functioning, right?

375 RJ: Eh, I think it's got some serious acoustic issues but most of them can probably be fixed with electro-acoustics within the language of the concert hall. Of all the public spaces, the concert hall is what Utzon himself feels is probably not so bad – not to say that he's thrilled with it. He can't see that it's bad enough to worrying pulling down and starting over. The long term strategic building plan actually sets up a strategy for what you can do on a longer run. Practically all of the public spaces should be simplified and can be easily reverted back to his original ideas. What the

385 Conservation Management Plan says – and it now a legal instrument, it has now been endorsed by the Government, so its part of the Conservation Laws – is that if it's a minor change you should work in the conceptual direction of Peter Hall. So if for example you need to make changes to the stage or the sound shell or the lighting or some element,

390 don't do an Utzon-element, work within the direction of Peter Hall.

AMDS: Otherwise they would scream at each other?

RJ: That's right. And if you do need total change, rework it

395 with Utzon. Don't rework it with another aesthetic and don't try to replicate what Hall would have done. And don't half-do it. Just treat each space at a time.

AMDS: I got the impression from Joseph Skrynzki that that was what Utzon wanted himself as well. That there had

been the sense in the architectural community before Utzon was reengaged that everything should be brought back to the original ideas, but when Utzon was approached that was not what he wanted, do you agree with that?

RJ: That's correct. There were lots of discussions to convince him that the Opera Theatre was so bad that he should start again. And I think his sense was that 'It can't be that bad, just do a bit of adjustments' and it's really only been the last twelve months he's realised and then reacted in rethinking the Opera Theatre. At first he wasn't really interested 'let's go and do something else'. He saw it as what Peter [Hall] did was functioning well even though not in his concept.

I had a photograph of the Opera Theatre and I said 'how can you even bear to look at this?' and he smiled and said – just before we had been talking about gardening which is an interest of mine – "well, every garden has a few weeds but that should not stop you from enjoying the garden." His sense was that 'of course it's not perfect, of course it's his [Hall's] design', but he honestly believes that now. He's aged and is looking back and I'm sure the answer had been different if we'd had the discussion forty years ago, but his answer now is that he knows that – in the fifties – to have gotten a building like that as far as he did, he was very lucky. Where else in the world could that have happened is his view. It wasn't many places in the world in the fifties because they were preoccupied with rebuilding after the war. It wasn't going to happen in other places more cautious and there were a whole set of curious reasons that it happened here. We botched our opportunity to get it perfect but we've still got something that is unbelievable. He knows that now because he's had so many people writing him to thank him for the symbolic aspects of the building. And in a strange.... it's that elusive quality of architecture that most architects don't ever achieve in their alive, they build a building that serves it purpose and all but never becomes involved, never becomes inspirational. And he did all of that with something that does not work, with something that is probably one of the worst opera houses in the world.

405

410

415

420

425

430

435

440

445

450

455

Matt: Aar, now you're exaggerating.

RJ: But it's true, where have we seen in any major city a worse opera house? And yet it doesn't really matter. Because the spiritual, the symbolic, the aspirational, those allusive things that building has got, none of the others have got them. You can easily get the functional, but to get the functional and the aspirational together, we can do that too now. So it's quite interesting.

[Matt leaves the room]

AMDS: So, another question. Another point – the collaboration with Arups. How has it been in this current project and also, it must have been affected by the way of working of Utzon, I mean that he always seems to take in some of the rules of the technical aspect and playing with it in the architecture.

RJ: He has an incredible understanding and I don't know whether... it appears to me totally intuitive but of course it can't be. But it appears so natural to be intuitive. He knows about these things because he thinks deeply and profoundly to a point to just knowing it within everything. So he knows that an acoustic surface that is convex will distribute the sound in an auditorium in a further and more equal distance and pattern than something that is flat. And that's an inevitable truth. He learned that from observation and from various discussions with Cremer and Gabler. And then he knew that that's part of a cylinder, 'how can I get a geometry out of that ceiling and how can I get a decoration as integral of the notion of the cylinder and the geometry as the froth on a wave is integral to the wave itself'. That's a part of the decoration of the wave where it breaks, it not something applied, it's part of the reason and path of the wave. So I think he understood about and clearly he has an extraordinary highly developed three dimensional mind and understanding of geometry. So he can imagine very easily sound because it's all three dimensional. The radii that Utzon used were 16 foot. We tried to use tighter curves to more easily fit the shape under the shells but eventually we ended back with the 16 foot. And these are still in development and still needs adjustment but we like it very much.

RJ: It doesn't need to be built. I'm not desperate to build it. Of course it would be nice, but, I mean, I could retire just knowing. Because the drawings have been done and we have heaps of documents so somebody else can have the worry of building it!

RJ: And there's even... there has been a great debate about the buildings in the closest proximity of the Opera. And most people misunderstood the reason the building has this iconic status. The white against the blue, the white against the city, the sculptural shape against the city....

[looking at drawings that RJ has brought in]

RJ: This was meant only for our own records so its not very rigorous, they're not meant for a publication. But what we did - every time we did a study - was that we summarised the study in one sheet.

AMDS: Ok

RJ: So, 2004 we were looking at an auditorium like this. In fact these drawings were done by Jan, in a workshop we had here that started with some discussions he had with Jorn. Based on these sketches, we made early models. The purpose of this study and the broad outcome... this is very superficial but its more or less a memory joker to us - about why we did this.

AMDS: Yes, that is going to be very helpful

RJ: [pointing to one of the drawings] You see..here we were searching for volume and not necessarily concerned about shape. Then here we were concerned about reflections and not necessarily volume, so we were not getting the volume. And March ... we were further looking at radial geometries and the ceiling was getting flatter and flatter while Arup was

getting more and more concerned about the reflections from the ribs and back to the stage. It would have reached a point, clearly, where it would have been completely flat. And of course most of these were studies, knowing that the auditorium would never be built like that. In this process I saw his several times, in Denmark, and we had discussions. And Jan came here several times. We emailed and sent models. [pointing to drawings] And here you can see the auditorium in the beginning of this year, when we started up again with a big consultant team and it became more and more interesting and serious. The radial geometry coming back and the studies we have recently been doing.

AMDS: This is a model you built, right

RJ: Yes, this is TriForma, a CAD model. All of our work is now in three dimensions. That three dimensional Cad drawing produces these drawings, these images and these models.

AMDS: Very handy!

RJ: Yes, and these drawings led him to the different balcony configurations and the adjustments. These were studies that we were looking at in September last year of circulation patterns. See the balconies are now like this, and he has taken these two out. He did not like the way the met the proscenium. And in January of this year we are now looking at different colour and slightly different configuration. That might be helpful..

AMDS: Definitely

RJ: Did you have any other question?

AMDS: No, it was only about the collaboration with Arup's and I think we'll take that the next time.

RJ: Can I just get my diary.. what might make sense is if we agreed on a time each week...

Interviewee: Richard Johnson, Director Johnson Pilton Walker [B]

Interviewer: Anne Marie Due Schmidt

Date: March 02 2005

5 Location: Meeting room at Johnson Pilton Walker, Sydney Office
Notes:

10 AMDS: I have a few questions and then I'd like to ask about where to find further information.

RJ: Let me just get a note

[leaves the room for a minute]

AMDS: One thing is the brief, if there is one as such. I

15 mean, as I understand it, you kind of developed what you thought should be the brief. But if there are any set or any paper saying 'we have come up with this', a number of requirements.

RJ: Not specifically. There is a detailed brief for back of house issues which I could get you. And that relates to dressing rooms and rehearsal spaces and back of house scenery dock etc. And that was developed by Theatre Plan in London on the basis of them being asked 'well what should a contemporary opera theatre have back of house?'

25 So I could get you that. In terms of the auditorium itself, there isn't a written brief. There is a requirement for 16.. in the order of 1600-1650 seats. There is a requirement for a state-of-the-art pit in terms of ability to change it quickly, ability to accommodate an orchestra with up to a 110 musician and reduce the size of the pit in various scales of orchestras. There is a requirement for world-class acoustics. And there is of course a requirement to change the auditorium back to be consistent with Utzon principles. And that is probably the brief. As simple as that.

35 AMDS: And that comes from the Sydney Opera House Trust?

RJ: That's right.

AMDS: And they wouldn't even have anything written or anything?

40 RJ: No, I think it was more verbal but I'll go through my records and see if there is a simple document or letter. I suspect there might not be.

AMDS: And as well – I went through what you gave me of drawings. And it's very helpful but where it is not so helpful is to understand what comes from acousticians and what comes from your office. Because for instance, in one of the drawings you write that you want to flatten the ceiling but I know from what you said, that that actually was more from Arups, suggesting that.

50 RJ: I think it is an interesting process and what we had been doing during that time was having fortnightly video conferences and tagging in Jan into the loop. So Jan talked to his father, he knew what the issues were, we would have video conference with Arup in London, and theatre plan also in London, ourselves and Arup in Sydney. And a project manager. Jan was on the phone rather than on a video because we couldn't link him, but he was part of

our discussions. And we would just determine as a part of that process what was the most beneficial thing to further explore. So you couldn't actually say that it was Arup or it was Utzon or JPW because there was a certain consensus that 'yes, perhaps we should explore this'. Sometimes we were exploring thing knowing that they weren't going to work to determine what to do. Would that for instance increase the reverberation time, would it give us odd reflections? We looked at for example where the octopus arch is, here [pointing to section through the hall], and we looked, one time, at kicking the ceiling right up here [in the gap between the two shells] and that gave us the required volume for reverberation time but it gave us the wrong reflections back to the singers. So a lot of things were actually discussed and abandoned. And some times we might say 'well, that won't work, but it'll be interesting to explore it to a point where we can model it because we might learn something from it.' So it was a value judgement, a collective value judgment... does that make sense?

AMDS: Yes it does. The only thing is – is there any recordings of those meetings?

RJ: I am not sure if there were... let me see if there were minutes take of those meetings. If there were it would be quite interesting.

AMDS: If you want to let me access them, of course you decide.

RJ: Yes

AMDS: But that would be very helpful because that is one of the points

RJ: That would track it right through

AMDS: Yes

RJ: What it wouldn't necessarily show you is the subtlety and the nuances of the discussions that went on, it would just show you an outcome. But let me see, Matt Morell would be the one to keep such records. I tend not to work on minutes, I tend to keep critical issues in my head and most of the things in the minutes are just words...

AMDS: Yes, most of it is discussions to get somewhere and what you decide is what you want to work on. Then there is a question about what level of secrecy there is about this project. For instance what can I tell people about it? I haven't told anybody anything yet, but I just wanted to ask you.

RJ: ...not so much secrecy but it's the same thing. It's common knowledge that the Utzons and ourselves and the House is looking at options for the Opera Theatre. That's common knowledge. It's becoming common knowledge that one of the solutions we are looking at is dropping the stage down. Beyond that, exactly how we are doing that and what it looks like is not common knowledge. And there are people that believe that the building shouldn't be changed... I think the sensitivity is, for example, none of these images [pointing towards the boards on the wall] are what Jørn himself would say that is what the auditorium is going to look like. The sensitivity is if we release any of these... these are not complete, they are preliminary

115 studies, leading towards something. So there would be people who have the view that nothing should happen, there are people, surprisingly think Peter Hall did an excellent project inside and he was much mis-understood and the interiors are not so bad and they should be kept.

120 And there are quite a number of people who feel that way. They are not very vocal but they do feel that way, and sometimes they are vocal. There is a growing view in the press, lead by Elizabeth Farrelly and a few other people saying 'what the hell is happening, we demand to know

125 what's happening on the Opera House. Why should Utzon make all the decisions, it is our Opera House, we should make the decisions.' Well, you can make the decisions when the study has reached a stage with a critical mass of information that you can absorb, but it hasn't reached that

130 level of information.
AMDS: So what you are saying is that if you released these [pointing to the boards] it would be taken as this was how it was going to look like.

RJ: Absolutely, you could not ever put a qualification on and they say, you know 'This is shocking; this shows that

135 Utzon has lost it, he'd never do anything like this or that'. Well, of course he's never done it, these are studies. So if he was in the process in his own studio thinking about a proposal and has sort of six months to study it and in the

140 end of two months somebody walked in and pinched all of his sketches and then published it in the papers saying 'this is what Utzon is going to do here', that's preposterous! Because some of the studies may in fact, like our studies, be to show a client what you shouldn't be doing. It is not

145 necessarily a study to demonstrate what you are going to do. So I think the sensitivity is to release the information in a way where it most accurately reflects the design intent. And we are not at that stage yet – we are very close to that stage, it may be another month or six weeks or two months

150 away. And if it takes another month after that, well so be it, what does it matter, it has been thirty years! Let's get it right. And don't release anything that will compromise achieving that objective. So that's the situation. And in your discussions with anybody... it is certainly no secret and it's

155 on the internet, the Opera House web that Opera House studies are happening. And you are quite free to discuss the fact that you are talking to us and to Utzon's and whoever and understanding what the process is. You won't be able to use any of these images till Jørn signs them off and I

160 won't use them because they are not his images. So we've been in a process of models and drawings reacting... well, even now and he's had these [pointing to renderings of the Opera Hall] for months and then, and he's absolutely right, he wants us to explore taking that balcony off [balcony on the lowest tier, closest to the stage] and these balconies

165 [balconies on the second tier, closest to the stage]. And of course you can absolutely... it is so clear, isn't it? We couldn't see it and he didn't initially see it either because he didn't comment on it when we presented it to him in

170 December. And now he's thought about it and said because it reflects the stepping of the podium – of course! It's

absolutely clear! And this is one of those things where if we rush off and publish or we rush off and show people what is happening, and they are super-critical 'we don't want this in our building' then the government will panic and think 'here is a huge controversy, why fund this? All we will have is grief' and then the job will die. So I think I've been more protective on this project than almost any because I think... we're at that very wonderful position of having re-established report with Utzon and he's feeling really good about all of that and he's been very, very productive and we want to continue. And if all of the sudden the press explodes with a whole series of negatives...

175 AMDS: It'll be the same old story again.
RJ: It'll be the same old story. And why would he, at his age, want to buy into a controversy? If barbarians at the other end of the globe want to act that way, well so be it, why should he get involved? So I mean I'm extremely protective because I remember how stupid I felt as an Australian at the time that we didn't have the ability to – at many levels at Government, politics and at a professional level – to see what a master piece we had. And we ruined our opportunity. I don't want to see that happen again. I think people whom I know to be supportive know an enormous amount and people that I'm suspicious of know nothing. And some

180 people are angry because they know nothing, like some journalists, and they try and write stories but because they have no information they can't write anything.
AMDS: No, that would be rather difficult
RJ: So it's better they know nothing because then they make it up and they look ridiculous. So it just needs to be carefully managed. Does that make sense to you?
AMDS: Yes it does and it is really very nice because it has been like... I have architect friends down here and they ask 'so what are they doing?' and I'm like 'I don't know, I can't tell you'

185 RJ: The best thing to say is that there is very serious analysis of what to do and shortly there'll be... when the studies have concluded and Utzon is comfortable with the results, they'll be published, but he needs time. And don't ask somebody in the middle of their design process to tell you what it's going to be.
AMDS: no, because they don't know
RJ: They don't know and they shouldn't show you. That's like if you were entering a competition for a design and you've got three months and suddenly at the end of the month they'd ask you to publish your ideas. It's ridiculous! You are still formulating your ideas and this is quite a complex problem, technically as well as aesthetically. I think what we've proved technically is that it can be done. There are no structural issues, there are no technical issues that will stop this happening and we are at the point of fine-tuning the imagery – how does it really look, what physical shape has it, what colour has it, how does it relate to the shells? You can see for example, when we did this drawing [section of the hall, with a thick perimeter around it that makes it touch the shell above], we did this drawing simply, quickly – although it does not look like a quick drawing, it

190
195
200
205
210
215
220
225

is - we did this to understand the internal volume. But if
 230 we publish that drawing, immediately somebody would
 say 'aarrh, look how ridiculously close this is up to here it
 is, you shouldn't do that' But we didn't draw that, that is
 not what it is going to look like because that is now being
 refined so that it sits in under there. But we haven't drawn
 235 that yet, it is quite complex to draw that. So these are not
 his colours, there is no reflection here. He is thinking now
 about changing these [the balconies mentioned before] and
 we are thinking about that this drawing [view towards the
 stage] is quite odd in the sense that it is showing too much
 240 light in the auditorium but nothing here. And then these
 drawings [same view but with a show on the stage] show
 an auditorium that is lit with the house curtain in place but
 it has a theatrical performance. Now, we know all this and
 we are in the process of trying to create drawings that Jørn
 245 is happy with, that gives the impression of his vision. In the
 appropriate time I'd be very delighted, very happy for it all to
 be public, but not now.

AMDS: One of my questions was actually also about the
 colour scheme. Because one of the sound technicians at
 250 the Opera House told me that the reason why the hall is
 black is because the players want it like that.

RJ: That was always the case. And Utzon knew that. And
 that's why these drawings are not right. And of course to
 try and replicate... again because this has been...all of this
 255 has happened within the last four or five months work,
 so it is quite a short time so we haven't got... and most
 of the focus was not in presentation drawings but was in
 understanding technical issues. We are now spending
 time on presentation drawings. But Utzon view was that
 260 if he could pick a dark colour here [on the horizontal
 part of the ceiling bands] and if the dark colour was tight
 around the proscenium [because only the horizontal part
 is visible here] then as the auditorium unfolds to the rear
 then the radial geometry would expand and this was the
 265 bright colour. Then the auditorium would get more and
 more brilliant in colour as you got back and darker on the
 proscenium.

AMDS: Ok, to make you focus on what is happening on the
 stage

RJ: Exactly. Now, if you then light the auditorium the way
 it would look, when...which is a complex thing to do... and
 of course it requires a lot more time for the 3d modellers
 that what we have done for this image. Because this is a
 very quick image, you just get some preliminary thing for
 275 discussion. But there'll never be as much light as this on
 here [the ceiling next to the proscenium] when there was
 a production. Cause the only light you are getting is spill.
 We are in the process of trying to understand. Even in this
 model, that is quite dark and then the colour comes as you
 280 come back. He was discussing it with me and he described
 it like a peacock's neck where the peacock is black here
 but as the feathers go back down - it's the same colours on
 the neck as in the tail - but the feathers fan out..

AMDS: ...and makes the colours visible...

285 RJ: ...and makes it visible and you get more and more

colour, which is exactly what happens in here. So I don't see
 that that is going to be a technical or aesthetic problem.
 He solved it in 1950 and he is using the same theory now
 but he is thinking about colour in... he is thinking about
 different colours. In those days he hadn't developed his
 290 ideas, he was thinking about gold...these samples came
 from him, they are not ours [samples of gold and china-
 red on the wall. Plus a new piece of birch with a lighter red
 painted onto it] Jan brought these just a few weeks ago.
 So he wants that colour in here [the dark on the horizontal
 295 strips] and then that colour [the lighter red on the vertical
 sides] here. And of course that is an approximation, we'd
 still need to create a sample in the real project.

AMDS: Yes, there are many tones of red.

RJ: That's right. And you can see here where the sides, and
 300 this was his original proposal, were gold and he had these
 images and he felt that no, that's just too dramatic, too
 colourful. He wants this to be dark but that colour is to be
 this colour and then for the wedges that come out to be
 gold. But this is still a crude rendering, I think the interior
 305 will be a lot more colourful, more interesting than that
 suggests.

AMDS: It would be very interesting to come and see it

RJ: Yes, I think... it is quite interesting that nobody has done
 an auditorium with that geometry. 310

AMDS: That was also one of my questions because when
 we spoke the first time you said that nobody had done
 anything like this. Which ideas is it you focus on when you
 say that?

RJ: The two things, well I suppose it is the same idea, but
 315 that is the notion of the geometry of the auditorium focus
 your attention to the stage and that the same geometry
 assists in distributing sound from the stage back to the
 auditorium, back to the people. And he had that view, and
 he is dead-right, that the acoustical requirements and the
 320 visual requirements are the same thing. And that if you can
 find a geometry, an architectural program or idea for the
 auditorium, where those things are in harmony, you must
 have beautiful auditorium because if you think about sitting
 in many auditorium, your eye is not focused on the stage,
 325 in fact most of the auditorium - look at Gehry's auditorium
 - the geometry billows and focuses your eyes into the
 corners or from the centre into the sides. The geometry
 runs across your view, not down unto the stage. Now many
 auditoriums may be more rectangular with ripples along the
 330 ceiling where effectively the eyes focused downwards and
 that's a natural outcome of the need for acoustic reflectors.
 But that doesn't accommodate the radial view into the
 stage, into a point where the actor is. That focus the view
 to the whole width of the proscenium. So I am sitting there
 335 [on the balcony in the new hall] and I am looking there
 [stage], it is different to there to there, but his auditorium
 effectively, magically, if you are sitting on the periphery it
 also... well look at that [a view from the side towards the
 stage] there you see it and the whole room is still [turning
 340 towards the stage]. I think if these instead had been that
 way [the ceiling creating lines the other way] it would have

been less satisfying. So I think that is what surprises me that nobody else has tried it. It is probably not astonishing if you talk to acousticians because the general acoustician will tell you that the radial geometry doesn't work, that is what Arup told us initially.

AMDS: But it does work now?

RJ: Or that this [ceiling curves] doesn't work, but it does work. So there are a couple of fundamentals... now, it took a lot of experimenting to determine what was the radius that would work and what was the right geometry for this [ceiling profiles]. And of course we had to change that because we've got a different auditorium than what Utzon had, it is bigger, and that this had that radius hasn't changed but the composition has. But of course what he is more interested in – and that is the extraordinary – I guess the idea in terms of how it relates to the human response rather than the physical form of it. So some would say 'ah, this is a fantastic shape, absolutely perfect' and the acoustician says 'well, yes, but that [one of the ceiling curves] need to be right there', and many architects would say, 'well, we can't do that because that'll ruin the interior' Utzon would say 'Oh, if it has to be like that, that's great.'

If he was convinced that it was a natural expression of the acoustics and that the environment would be better... AMDS: ...then that would be right.

RJ: ...that would be right because he is working with natural, organic systems. I don't think people understand that, I am sure people don't understand that. Because they work from a formalist view of architecture that says 'wouldn't it be fantastic if all of this sat in a sphere, that'll be a wonderful thing, to make a sphere sitting here on this black podium with-in a glass-sphere and then they fit the building within that. But his form comes from 'how can I... when I approach this building, how do I feel, how do I relate to place, what happens to me that instant when I walk in there, what do I see when I sit down' and that's all about that sort of things. And the form is not the outcome of the architecture.

It is the human experience that is the outcome of the architecture. The form is one part of that. But a think a lot of commentators really don't understand it.

AMDS: I think also it is a bit unfair when he is sometimes said to have this free form because this is not free form

RJ: no, it's very, very determined.

AMDS: Yes, it's very determined. Of course, within those rules that he then sets up he can play with the form and shape it as he wants to. But only within those rules. Sometimes I get a bit annoyed when people say that he just thought up this form and then tried to build it. It is actually very well thought out.

RJ: Yes. I think... there is a quote that 'within the idea there is all that is necessary to build or execute it' and that is right, so you can say 'well, this is an example of that saying, where because he knows about geometry and because he knows about acoustics, because he knows about dispersing the sound, because he knows about how the radial geometry would work acoustically and visually this is a strong conceptual idea, that had within it encompasses

everything necessary to realise the job – to make the acoustics work, to make the lighting work, to prefabricate this to get the finishes right, to adjust it subtly during design development, initially it was wrong. I think that is his skill, that is his great genius and I think it is a genius that comes from profound reflection about things. A lot of people has obviously tried to design opera theatres or auditoriums and they... there are so many technical issues lighting – that needs to always be in a certain position in a certain angle through here – a certain depth of the orchestra pit, a certain angle for sight lines and certain volumes for reverberation time and blab blab blab. And you can get bombed down in a mile or kilometres of technical fact or requirements. They understand them each individually and solving them individually won't produce a great auditorium. It is finding out what is the essence of those and how do they affect you as a person and as a performer, how can I harness those things and in the end not be constrained by them, not allow them to dominate the idea. But if the idea accepts them...

AMDS: yes, then they can be accepted as well

RJ: they can do whatever they need to do. So if you accept that the acoustician say 'well, I need that angle [of the ceiling profile] to be a bit more that way, because I need that [reflection to the audience] to come down here', then you can say 'oh, fine'. And I think... we haven't got to that degree of subtle refinement yet, we are at a more crude level of analysis but that cruder level of analysis tells the experts that it is possible to make it a great auditorium because without the fine-tuning we are hitting all the right design targets [pointing towards Odeon test diagrams]. So if we, during the finer level of analysis that there is a dead spot up here, we can make local adjustments. And because the thing is not absolutely, perfectly, geometrically fixed to a point as a piece of sculpture, where you can't move anything, cause you can move every one of those things [ceiling profiles] and there is no better or worse. The best solution, for Utzon, is the one where the acoustics is right. And it'll be the most beautiful, visually as well, I think. And that is the joy of it. And it is a bit like, you know, the most beautiful tree is the one that responds to its environment or responds to its place. And you'd see wonderful trees in rocky, wind-blown cliffs, down the south coast. The wind comes in and they grow and they protect themselves. And you look at them and you can see the wind – and it is not windy – and you can see the rock – and you can't see it but you know the soil is not very lush. And you know the age of the tree. You can see so many things in the nature of the tree because as it's growing it has adjusted to all of these forces and inevitably when you see it you think it is absolutely wonderful and there is nothing that you'd possibly want to change. And he gets that from nature, doesn't he, he gets that from actually sitting there and profoundly looking at the lessons that you can learn from nature and profoundly knowing how people respond to things. How they feel or walk or hear.

One of the things that has fascinated me... and this is a

speculation on my part... he has protected his working life from project and his association with client in the way he has run his practice to allow himself time to think, to allow himself time to reflect. Not to be tied in to other people's programs. Even when he was in Sydney, he had an office in Palm Beach. He could have been on the site every day but he didn't do that, he retreated out there. He needed that. I wasn't close, I didn't know him in those days, but when you listen to somebody like Richard LePlastrier... he'd go sailing or he'd go sit on the beach staring on the clouds. He has this sort of relaxed... he's working, he's working on a fundamental level, he is not wasting time drawing, he is not wasting time solving problems that are peripheral or that you can't solve before you get to the core of the problem. He is attacking the core of the problem. It's quite curious to me because, I think, in contemporary world the architect's program and process has been shanghaied by contemporary project procurement manners, more particularly in this country than in yours, that start to act as real constraints on how you develop your drawings or how you deliver your projects. You know they want to see you every week. And you might need three months of thinking on something and then you can start to talk to someone but you don't need them in that time. But if they need you, they set up all these deadlines or all these deflections, then you haven't maturely developed your idea. It'd be a bit like if when Beethoven was composing his fifteenth symphony he had to report this to a client every week... 'How is it going, Beethoven? Oh I don't like that node there - that is never going to work. Look I suggest you do this'... you know, he doesn't need that advise, he needs time to put it all together. There are certain things, technical things that you constantly need to absorb and in a way in this project again you see, he can work where I am dealing with those day to day.

AMDS: You are the buffer?

RJ: Yes, I am the buffer. And Jan is the buffer when he is here. And we can both filter and he trusts us enough to say 'so what does all this mean'. And he'll never question a real requirement, he'll never say 'well, that's ridiculously, they can't have that'. Many architects try to ignore a requirement if their idea doesn't accommodate it. If it is a real requirement, he'll change his idea because he's a real practical, pragmatic architect - profoundly. And quite different to what people in this country thought of him when he was here. Quite different. You constantly say... when we were doing work on the Utzon foyer he'd say 'how big can you get a piece of plywood' and there'll be 'oh, can't it be bigger' or 'can't it be smaller', it's just 'oh' and then it is accepted and then it is a natural order and you accept it. And you might reject it if you try it and it doesn't work, but generally it will work, you can make it work.

AMDS: And sometimes it even makes it easier if you know that size and say ok, that could give something to the architecture.

RJ: Correct. It is a natural order. I am not sure whether it was on a program that I saw on television or whether he actually did it in one of our meetings but I know clearly that I've seen him with a rock - in the Majorcan house - with a rock, a leaf and a twig and he puts them on a table and he says 'there, these are the elements of nature' and then he looks out over the Majorcan valley 'look what you can do with these simple elements, you can create this'. It's very poetic and it's absolutely right.

AMDS: With a few elements you can do everything.

RJ: That's right. But you need to know the inherent nature of the elements. You know, what can you do with a stick. He's got this piece of wire sculpture in his Majorcan house, Can Liz, and... no it's not Can Liz, the one on the hills...

AMDS: That is Can Liz, isn't it.

RJ: Oh, yes, the first one is Can Feliz, this one is Can Liz, yes. And I admired this sculpture, it's just this twisted wire sort of tree-dimensional sculpture and I admire it 'it's fantastic, you know' and he said 'I was walking and I saw a twig and I thought it was a beautiful shape. And I liked it so much', he said, 'I took it down to my local iron or blacksmith and said 'I'd like you to make me a sculpture of this in square rod like this, you don't need a drawing, do you?' 'No, I'll just make it like this'. And this ability to see things in nature and see a habit ... Richard LePlastrier gives wonderful talks on his understanding of clouds 'cause he is a sailor and of course I've been to your country and I've learned how important clouds are. And you know it is a very, very interesting sky-scape, quite different to here. And I can see how being able to read and understanding the different cloud formations is quite a study and quite profound. But that tells him quite a lot about organic shape and relationship between these shapes and the horizon and about light and about diffusion of light and the greying off of colour. I am beginning to understand artists like your... a twentieth century artist, what is it...

AMDS: Ahh....Hammershøj

RJ: Hammershøj! Absolutely wonderful, unbelievably beautiful, unbelievably. The first time I saw a painting of his I just couldn't believe it and then I searched for more and then I bought some books but that's Danish light and that's Danish colour. That is an understanding... and within it, in those pictures that appear to a foreigner to be black and white, there are all the colours that you could ever want. That's wonderful. The interesting this for us is of course... we study history of art, of course, and history of European art of course but it doesn't encompass Danish artists.

AMDS: No, they are not very well known.

RJ: Nor does it encompass Spanish art terribly much other than the obvious. So our heritage is very focused on the English. Europe as England and of course Europe is not England.

AMDS: No of course not

RJ: And the English are not visually literate. They are literate, but not visual. They don't have great architects and artists and sculptors, they have individuals that have done things but serious aesthetic movements they don't have, I don't believe.

AMDS: You think so, that is a new thought to me

RJ: yes I know so. I'll tell you. I learned about historic architecture from Ashworth, who was the chair of Sydney Opera House Trust. And he learned what he was telling us from Banister Fletcher which was history of architecture by the comparative method, which was to compare everything to England. And when I first went to England I was very disappointed because I could see these buildings that were supposed to be brilliant and fabulous and they didn't do anything for me. And then I went to Rome and then I went to Athens and then I saw the real source

AMDS: Tracing history backwards.

RJ: And then I went to other cultures like France and Spain and saw how they progressed those ideas and had taken them on as their own with a new vitality and what I saw in England was that they'd copied them badly. And my sense is that other than a few periods, like the Georgian period, there is little of any consequence in England, very little, and the same in art. But I can't say that it is the same in literature, of course, I can't.

AMDS: Would this re-engagement of Utzon have been possible if Hall had still been alive, do you think?

RJ: Interesting question....Utzon has very generously suggested to me that he does not blame Peter Hall for what happened. I do.

AMDS: You do?

RJ: I do. He should not have taken the job. He ruined his own carrier, Peter Hall, he was a fine architect. He did some extremely good work but didn't understand Utzon's method or his architecture and didn't develop his own architecture. And ruined himself in the process, so in a sense he is a rather tragic figure, Peter Hall. Utzon doesn't blame Hall at all. He would never say and has never to me said 'look how poorly this is, how shocking it is', he blames...he doesn't blame anybody just sees it as the architects were part of the political pawn [hostage to fortune]. I think now he reflects back in a very gentle, elegant and generous way that Peter Hall was just a political pawn. It would have been, probably, more difficult if Peter Hall was alive I would suspect but I don't know. I knew Hall quite well – I had no respect for him. I had respect for his talent that he didn't develop. As a young architect, prior to getting involved with the Opera House he could have made a great carrier of himself in his own right and he ruined all of that. I look at him rather sadly and think that he was a fool; he was a talented man who just made the wrong judgement. And then was used by people – it could happen to any of us, it certainly could happen to me. And if I felt that it was ever going to happen, I would resign immediately. Absolutely – no question.

Because the only reason that I am doing this job is because I feel the debt that I am in a position to be able to pay back – some of it. But if I were cold and calculating I would never have gotten involved. I have my own work and my own practice to develop. But of course I am getting a lot out of it, an enormous amount.

AMDS: But you also know that no matter what, there is going to be a big debate.

RJ: Well, I would hope that we are mature enough now that the debate will be sensible. If it gets ridiculous then if Utzon walks away, I'll walk away immediately. I don't want to have anything to do with it. I don't need it. The people having a debate and no doubt you have met some...

AMDS: ...no, not really...

RJ: they don't even begin to understand Utzon and they just...the jealousy in the architectural profession is shocking. It is the same in Denmark, I know. And instead of saying 'this is not how I would do this but it is really good work and well done' they go 'how did he get this commission, what is he doing' and I think it is terrible. It is the same attitude that was here when Utzon left in the 60ties. The profession as a whole didn't actually come right out and were against him but they didn't support him. And nobody is supporting me in what I am doing, not a single person. They are waiting for me to fall on my [speer] and I don't care. But you watch... there are people who will try to drag you down. That is human nature. Fortunately I don't care. But I do care if they kick up a fuss to a point where Utzon says 'well, thanks very much, but it's all too hard.' That would be tragic. Absolutely tragic. I am pretty hopeful. We've got it a long way anyway and to my mind if all we do is drawings of what is possible and the Utzon-room and the western foyer and the Utzon principles and the fact that he is now a very contended man. My god, that is enough. That is enough. We don't need to build anything, he is happy. At the end of his carrier after giving so much to this bloody country he at least knows that not only... because he has always known that there is a number of people that love and support what he has done... but that there is a formal gesture at the Government level of a connection back – I think it is really terribly important.

And I think it has given him the sense that he doesn't need to be as protective. He is certainly more involved now in publishing and with talking and... it is hard to know, and I am not in a position to know, whether the reengagement back with the Opera House is assistant or has any influence on it or not but most likely it has.

AMDS: Probably it is the dot over i.

Interviewee: Richard Johnson, Director Johnson Pilton Walker [C]
Interviewer: Anne Marie Due Schmidt
Date: July 21 2005

5 Location: Meeting room at Johnson Pilton Walker, Sydney Office
Notes: The Golden Book that is referred to in this interview is a document compiled by Johnson, Pilton, Walker with input from the various consultants, which
10 describes the current design development. The name is in line with the Utzon presentations of the Opera House project – The Red Book, The Yellow Book and The Blue Book.

15 RJ: And the problem is that the Premier, who has seen this [Golden Book]... latest set of drawings and is very, very enthusiastic about it, has given me instructions not to show anyone.
20 AMDS: okay
RJ: now...I mean publicly show anyone. They don't want it to appear in... eh...they are in the process of discussions with the Federal Government as well about funding...
AMDS: Okay, that's really exciting if that's going to happen.
25 RJ: And there is world heritage listing, as you probably know. So... eh... really we're not doing any more work, nor is Utzon on the Opera Theatre. It is sort of resting...
AMDS: Yeah, laying there and waiting for Norman to convince somebody to fund it, yes of course
30 RJ: But I'm happy to take you through this document, would that be useful?
AMDS: Yes it would and also I have some questions, actually
RJ: oh, good, let's do the questions first
35 AMDS: yes, I don't know... we should also watch the time because how long have you got now?
RJ: about an hour... is that alright
AMDS: about an hour, yes that's fine. ..just to cut somewhere. Eh, because I've been writing through
40 the whole case and trying to describe it and of course some questions emerge and some of them are of course connected to the documents but it is actually not so much eh....the Gold Book that I need, I mean because that is going to be published at some point and probably I can use
45 it before I finish my Ph.D. anyway to put it in.
RJ: Right
AMDS: It's more to do with the process so I might not so sensitive.
RJ: No, I don't think it is.
50 AMDS: But we can take that as the last bit.
RJ: Alright
AMDS: I was thinking... because when you were chosen as the Opera House architect, in 97?
RJ: probably....[laughter] you probably know more than I do,
55 but around then.
AMDS: yeah [laughter]....it was on the basis of a competition, right?

RJ: It was. It...it...it was....In 97 the Public Works Department, which is the Governments architects, as you know, did a master plan for some improvements to the Opera House...general improvements.
60 AMDS: okay, as the exterior or interior or all of it?
RJ: all of it... it was an early document that was looking at fixing up disabled access and a number of other issues in time for the Olympics
65 AMDS: ok
RJ: and it...it...the scope of work was about 70 million and they were looking for... architects to be appointed to implement that work so they had ...the Government and the Trust were sure they would get 70 million from Federal funds because there was a billion dollars earmarked for
70 bicentennial ...ehm...bicentennial...was it bicentennial? No, for federation funds which was for the turn of the century.
AMDS: Alright
RJ: and these were seen to be for prime projects around the country...and nobody thought that the Opera House...
75 everybody thought the Opera House would get a modest amount of money out of it....of a billion dollars...it turned out that they got nothing.
AMDS: Alright
80 RJ: and...and....but, they didn't know that when they interviewed
AMDS: ok
RJ: When they interviewed, they...ehm...advertised generally for expressions of interests which... I don't know how many
85 people in Australia entered
AMDS: architects only or?
RJ: architects, yes, I have no idea how many but they short-listed it to six practices, Sydney practices. Ehm...including my previous practice...ehm...and I...we as a partnership
90 decided to express a strong interest. I was personally a bit unsure of whether I wanted to be involved in the Opera House. So....but my other partners were absolutely clear that this was a job for us.
AMDS: alright. And why weren't you sure?
95 RJ: because of the long history of the building and because the more I red the master plan document, from Public Works, the less I agreed with it.
AMDS: yeah
RJ: So I took a very arrogant position in the interview. We
100 were short-listed and then I went in and virtually told them that if they wanted somebody to implement that plan, then I would leave the room because really we didn't ...I didn't agree with the plan and they'd be better of interviewing somebody who was able to implement it. But if they were
105 interested in knowing how I might proceed with the project I was happy to stay there and talk to them.
AMDS: yeah
RJ: the chairman asked me to continue. This was Skrzynski. And...ehm...so I mapped out a strategy which was not
110 that dissimilar to what's actually happened. I mapped out a strategy of how one would approach the work at all...any work in the Opera House by getting back to some fundamental principles and ideas and that if I was

- 115 appointed I would do my best to try to re-engage with Utzon.
'How am I to do that', they said, and I said 'I have no idea
and it's probably not likely but it is absolutely critical that an
attempt be made.'
AMDS: yeah, okay
- 120 RJ: And I talked to them in broad terms about not doing
any work anywhere until we understood the principle ideas
behind the area. And I had a set of diagrams that showed
how one might approach work anywhere in a building.
And ehm...we were appointed. Now...but before we were
125 appointed I thought the interview had gone very badly and
my other partners were very critical of me, they were very
rude to me after the interview because they said 'you've
just blown our chances of getting the job' and I said 'I don't
care, I don't want the job,' but we want the job,' I said
130 'well, you should've presented it. This is how we should do
the job or we don't want it. It's poisoned chalice. Whoever
does this job could ruin their practice... or you might do the
job and be able to influence'. So what then happened was
that Joe Skrzynskiehm...decided before he appointed
135 us to say, that we were preferred, that he needed a couple
of interviews, he needed to look at our previous work, he
wanted to look at my work, he went down to the then head
office in Melbourne and looked at the Melbourne projects,
talked to the Melbourne partners, who were written into the
submission and then ...and then interviewed me - again
140 - and then determined that he didn't want to appoint the
practice, he wanted to appoint me.
AMDS: ok, right
RJ: And I said 'that's not possible, you can't appoint an
individual', because I had no insurance, I needed the
145 support of a practice. So they then...then appointed me
as an individual of my practice, so it was an appointed of
Richard Johnson of the previous practice.
AMDS: That's quite unusual as well
RJ: Well, not necessarily unusual but it was in a sense a
150 specific thing that the job was given to me, not to any of
my other partners. That meant that when I changed the
practice from my previous partnership to this partnership,
none of the people changed, we stayed in the same
building, my previ... other two partners, who were in Sydney
155 with me for twenty years came with me in the new practice
and then I said to the Opera House 'I've changed my
partnership, is this an issue?' and they said 'no, it's not an
issue, we've appointed you.' So...I mean that's why...that's
how the appointment happened and just consistent with
160 me saying 'I won't implement this masterplan'... they
realised that they were not going to get funding for this
70 million worth of work anyway and I think Skrzynski had
already tweaked to....he was already on the intellectual path
of knowing that the masterplan that was then done was no
165 good and knowing that there needed to be a more strategic
or more over-view approach and when I presented my
proposal I think it crystallized with his embryonic ideas and
he could see a way forward that made sense, so I think....
AMDS: yeah, so he didn't necessarily have the same
170 opinion on beforehand but he understood it and saw...
- RJ: I'm not sure, to this day...I will never know whether
he was thinking in parallel but I think....he intuitively was
thinking in parallel but he didn't have....he hasn't got the
background to have thought through the strategic steps in a
professional sense because that's not his area. So I mean 175
I think it was just a fortunate set of circumstances. And
then...then he set up a group of people who would advise
him, eminent people, people who had also been associated
with Utzon in some way or another in the past. The initial
180 response from that body was 'don't trouble Utzon, don't
approach him'...
AMDS: right
RJ: and that was pretty universally felt but I didn't agree
with it.
AMDS: no 185
RJ: and I said...well I wasn't very vocal at those meetings
but in my mind I thought, 'I cannot proceed on this
project'...I was getting terrified then because I mean, this
is a very honest discussion...I didn't really want the job.
190 If I ever was...If I was in my own practice at the time of
expression of interest came, I would never have expressed
an interest in the job
AMDS: no, alright.
RJ: and because I was in another partnership, with great
pressure from my other partners and I thought I'd get
195 eliminated in the first round by speaking my mind but I
didn't and then...then I found that I had this project and
the only way I was going to do it was if Utzon...with Utzon
onboard and if I couldn't do that - this was a resolve in
my own mind - I would leave the job because I wasn't
200 going to be stupid to ruin my reputation and become
another Peter Hall. Because that is what Peter Hall did
...Peter Hall is much maligned in that he made a foolish
error of judgement to take on that project - in my view.
But Peter Hall was a fine architect. And I'll say that. He was
205 unfortunately foolish because he ruined his carrier.
AMDS: Yes
RJ: But if you look at his early works, and...and you view
them in the context of the time and what other people were
doing architecturally he was....he was potentially a very fine
210 architect.
AMDS: yeah
RJ: no question in my mind and....he was used as a pawn
and the whole position contaminated him... and it ended up
killing him - he died a young man, relatively, anyway...that
215 was beside the point... and I was acutely aware of all
that and I didn't want anything to do with that. So I wrote
- against... advise - I wrote to Utzon and I thought 'Even
if I continue' - I was still in my old practice whilst this was
going on and I was thinking 'I can't resign, I've got to try and
220 get him involved'. Meanwhile we were doing more studies
of the strategic nature and I was getting more and more
interested in the project
AMDS: Yeah
RJ: and ehm... I had always had a passionate interest in
225 the project from student times. And so a lot of....a lot of....
whatever literature there was I had read and I had certainly

crawled all over that site during construction – illegal over the fences as students do, but I wasn't known to be an expert in the project and I wouldn't have considered myself an expert but as it turned out I seemed to know, you know to know a hell of a lot of the job compared to what....well most of the information in the public that had been published, I had read and tried to understand ... and...ehm...I knew I had to write a brief....even if I wished to do the job, it is ethical and polite even if Utzon had no intention of being involved or I had no intention of involving him, it was professionally, ethical and correct procedure for me to write to the architect of the building that I am now responsible for.

AMDS: yes
RJ: and to advise him of that fact
AMDS: certainly
RJ: so I made the judgement. I didn't care what anybody was advising me. That was what was required. And that I would attempt to write something simple, elegant, minimal, no more than two paragraphs – short, succinct paragraphs - that might embody within them something that might imagine in his mind that there might be somebody who is writing this letter who understands... or who might begin to understand the building and its importance. So my attempt was two short paragraphs, a request to travel to meet him at any time to suit his convenience. And...and a beginning that I...nobody has any right...or...ehm....expectation that could call upon his time because he'd given so much.

AMDS: Yes
RJ: And that I didn't want to trouble him in any way and that it was my obligation to advise him about the fact that we'd been appointed and that should be of the mind to meet me, I'd come at any time, anywhere....and whilst that letter went out, I'm sure that Skrzynski – independent of that – was...had discussions with Lin [Utzon] and...and...and the House was trying through Lin to send warm messages to Jorn

AMDS: yeah
RJ: and they'd made several gestures that were more than gestures to indicate that they were of honourable intentions. And it was just a good set of circumstances. I have no doubt that Lin would have checked out, through her contacts, who the hell I was

AMDS: yes certainly
RJ: and I wasn't a high profile person, still I'm not. So that...that essentially it wouldn't have been necessarily easy to find out who I was. Unless you spoke to people who really knew.

AMDS: yes
RJ: So...somehow...I have no...I have no doubt that...that...the letter, Skrzynski's approach, whatever other people had told them when they'd enquired have all said 'well, there's nothing to lose by meeting them'.

AMDS: Yes, Skrzynski was telling me about this dinner that he had at the Opera House where he invited everybody who were vocal and interested in the Opera House. And that was after you had been appointed?

RJ: that's correct.
AMDS: were you there?
RJ: yes I was
AMDS: and did you help arrange it or was that Skrzynski?
RJ: no, Skrzynski did that. I wouldn't have done that and he was right. He was absolutely right to do that. But the advise in that meeting was 'don't approach Utzon'.

AMDS: Ok, so that was the general ...
RJ: That was the general opinion....everybody changed their minds very quickly after things started to change. And particularly when I had a date and...and...and an agreement to meet. And then all of the sudden everybody was supportive of the idea. I think in fairness also because a lot of people said 'don't approach him because you'll upset him'

AMDS: yeah
RJ: 'don't approach him because he'll say no and you'll upset him', 'don't approach him because who are you to approach him'. For all of those reasons but for me I had to find a way of approaching him that was acceptable because he had to be approached, it was a matter of professional ...ehm...ethics that such a letter be sent.

AMDS: yes and even if he said no, then you had his opinion and that was a way to proceed or not.
RJ: exactly. If he had said no, I would have been in a dilemma because I wouldn't know that I would have wanted to continue on the project and then I would have had to have dealt with my other partners. And of course...what had happened then was in the time between me being appointed and Utzon.... and Skrzynski politicking, which he did very brilliantly and seeking other opinions and lobbying Lin and me sending a letter and getting an audience, I had been doing some planning work on the building.

AMDS: Yes?
RJ: Seriously looking at what are the issues or problems, further developing my ideas about how to proceed and absolutely in my mind cementing the notion that the Utzon Design Principles was the first fundamental way of proceeding. So when it came to the point of...and whilst this was happening, parallel to this, there were eminent architects of the city who were meeting the Premier like Harry Seidler and Glenn Murcutt and they were telling the Premier you've got to get Utzon back as a consult him blah blah blah blah. They were not necessarily aware of what was going on in detail level, some...well Murcutt was but Harry wasn't necessarily because Harry wasn't in the meetings that Skrzynski was holding but certainly they were an influence to the Premier and when there was a date and a meeting there was the notion of 'well, what are we going to offer him? What are we going to do?' and I'd already been appointed for a scope of work that didn't exist because the 70 million

AMDS: Yes, there was no funding
RJ: – there was no funding. So it was very clear to me what we'd get him to do. We'd get him to write the Design Principles.

AMDS: yes

RJ: and...and...my sense of it was that it was something you could ask him to do easily because all he had to do was to talk into a tape recorder...

345 AMDS: mhh, yeah

RJ: and then any translation or any drawings or any supplementary information could be organized by Jan or us. And the hope was that once he got stuck...once he got into the design principles, that he would...that it would be a cleansing process, a healing process that ultimately would get him reengaged with the detail of his own building again. And that even at the end of the day if the Design Principles were not an important document - which I believe it is, I believe it is absolutely fundamentally important - it was the process by which he became involved and interested in the detail. And when...so...so...when the Premier and the Trust said 'what are we going to offer him?' Murcutt and Seidler were suddenly offering him the consultancy for all the new work but there was no new work

350 AMDS: yeah, no

RJ: there was no money. So he was offered a role as advisory consultant to the Opera House - vague...no scope.

AMDS: but did that role actually change.

RJ: absolutely

365 AMDS: Politically...I mean it did of course practically of course - how he was engaged and how he was actually involved in the design but was his 'title' or his 'employment' or what you should call it, was that changed as well? Because it seems like...

370 RJ: it was

AMDS: first there was this idea with the design principles

RJ: it was

AMDS: and then after that he was appointed as the consultant

375 RJ: correct

AMDS: alright

RJ: what happened was that there was a letter that the Premier wrote...ehm... Skrzynski drafted a bit, I drafted a bit, the Premier's department drafted a bit and the Premier signed it. Sort of saying all the right things then offering him a role as consultant, unspecified for what and I was to take this when I went to see him. My real mission was to get him to write the principles. So I put the principles as the consultancy.

380 AMDS: yeah

RJ: And the first thing he did was...he was...he was so generous and so warm and...ehm...I was petrified with meeting him because - as you would be

AMDS: yeah

390 RJ: - but more particularly because I didn't want to cause him grief, you know?

AMDS: yeah

RJ: more particularly because, you know, I perceived him as a man of the same age or the similar age to my father and I knew exactly how people of that age work, you know, and I didn't want to come and rake up all this sort of stuff; all the problems of the past, nor did I want to put any unreasonable expectation or pressure on him to do anything. He didn't need to do anything...unless he wanted to do it

400 AMDS: yeah, but just you showing up is actually...I mean... potentially a threat

RJ: threatening, yeah. And of course as soon as the meeting was set, everybody back here had these great expectations that I on my own would go over there and meet this famous man and somehow or the other everything would be solved

405 AMDS: yes [laughter]

RJ: and, you know, nobody came with me [laughter]

AMDS: no

RJ: and I was thinking [clutching his head] 'Oh, my god how can I cope with all of this', you see, I...he was so warm and generous and we spend...we spend a very long first day together the first day; talking about all sorts of things. He picked up the Premier's letter and was very happy to receive it, very, very happy to receive it.

410 AMDS: yeah

RJ: and put it down was of course is impossible, you see. And then discussion, discussion, discussion about opera, architecture, historic buildings, Palma, you know, German invasion in Mallorca, the impact it has had on farms and so it went on and reverting back to the times in Sydney. It was the most beautiful rambling discourse of ideas, current, past - fabulous - and all the time he was testing me, all the time, and Lis was sitting there, like a hawk. Whenever he or I shifted the discussion into a troublesome area, she would change the subject. And ehm...and of course I was sensitive to all of this. And he then said to me... at the end of it, he said...because I kept gently persisting...ehm...and he then said...ehm...'I need a break tomorrow to think about this' and he suggested a number of things that I should look at in Mallorca and...ehm...which of course...and I came back to the hotel and I rang up Skrzynski and I said 'I'm sorry Joe but I've blown it; there is absolutely no way he's going to get involved. Absolutely no way.'

415 AMDS: yeah

RJ: because it was an elegant brush-off. He was flattered that the Premier should write a letter, he was flattered that I should come and deliver it, he was flattered that I knew so much about his building, I'm sure - and loved it. And you can't fake that, you know, you do...you do know...he knows if you know

420 AMDS: yes

RJ: he also. there're so many subtle little things, you know that...that...and again that's the sort of...I knew him through my father's generation and I knew what he was thinking in some things

425 AMDS: yeah

RJ: you know there was a common ...a common point of discussion for example in those days, maybe still is in some...I don't know whether you know but in Australia of course the great diva was Maria Cal...ehm...ehm...Joan Sutherland an absolutely wonderful voice. And the great debate was of course 'who is the best diva. Is it Maria Callas or Sutherland?'

430 AMDS: Oh..

435

RJ: And there was of course – how would you answer it?
 AMDS: I have no idea!
 RJ: Because the interesting answer was that his answer
 and my answer and my father's answer was that 'Callas is
 460 the best diva'
 AMDS: how come?
 RJ: because she...she...she had not so good a voice
 compared to Sutherland but she had intellect, she had
 the drama, she knew about the total experience of opera,
 465 she was a great actress. She was the epitome of being the
 opera diva. But her voice – of all the things she had – the
 voice was not as good. Sutherland had the pure voice,
 she could sing absolutely any tone pure, comparatively no
 – very smart – but comparatively little intellect. Brought
 470 no real depth of understanding, looked appalling, no great
 glamour, no great acting skills, she'd just stand in the
 middle of the stage and sing these unbelievable beautiful
 notes – but that's not opera.
 AMDS: no
 475 RJ: and that was well-known by....well, if you'd ask certain
 types of people of that generation they would have definitely
 fought for Sutherland. No question in their mind. But
 then there is a certain thinking type of people who would
 definitely be in Callas. And I was fortunate enough to know
 480 exactly...and then he told me this wonderful story where
 Sutherland who had been rather critical of his building
 eh...sent Bonyngé, her husband to... who was conductor
 as you know, to...he came to look over the building towards
 the later stages of Utzon's time here and at that stage the
 485 building had reached a sort of an international statue of
 being something extremely promising. And so Bonyngé
 started to show more of an interest in the building that
 Call...Sutherland was still vaguely sort of critical of... And
 Bonyngé was in the shell of the opera theatre and he said
 490 to Utzon 'Mr. Utzon, how good are the acoustics, what are
 the acoustics like?' and Utzon said that he said to Bonyngé,
 'Maestro Bonyngé', he said, 'the acoustics of the Opera
 Theatre will be so good and so perfect that even your wife
 will sound like Maria Callas!' [laughter]
 495 AMDS: Wauw [laughter]
 RJ: whether he said that is another story but it is sort of this
 wonderful story. And another thing that was happening...I
 came back after the day, the break, and I had been
 crawling all over Palma and the cathedral was one of the
 500 places where he'd told me to go, and I'd been crawling all
 over the cathedral thinking 'what the hell is he going to ask
 me?' on the following day. And we had been talking about
 – among many things we discussed - how the glass were no
 longer made in France and there were no more supplies of
 505 the glass and that eventually....and wasn't performing very
 well in terms of heat loads and this sort of horrible colour
 wasn't what he'd planned and that it was sort of ghastly...
 AMDS: oh, here [at the Opera House], I thought we were
 talking about Palma
 510 RJ: Here, yes, there is a link to the story because when
 we'd been talking the day before about the glass and I said,
 'Look, there is an opportunity' - I was trying to tell him that
 now is the time to get back involved because there are a
 number of changes that are needed to the building and
 either he does them or they don't get done. 515
 AMDS: yeah
 RJ: and his view at the time was 'leave it alone', leave it
 alone. And...ehm...and I was saying to him, 'well you can't
 leave it alone because eventually that glass is going to –
 quite quickly, maybe within the next ten years perhaps - that 520
 glass is going to be replaced and there is an opportunity to
 then re-engineer all of the supports back to your conceptual
 idea'.
 AMDS: yeah
 RJ: and anyway I came back after and 'Did you go to Palma 525
 Cathedral' and 'yes, yes' and I'm thinking you know, 'I'll
 jump at it before'... and one of the most stunning things on
 the cathedral - amongst many things – but one of the most
 notable pieces is this extraordinary rose glass windows.
 Have you been there? 530
 AMDS: No, I haven't.
 RJ: It is really extraordinarily beautiful sort of twelfth
 century...ehm...so he said, he sort of asked general
 questions 'what did you think about Palma Cathedral' and
 I'd go 'fantastic, dadadadada and the rose-window' and I 535
 was sure he was going to focus on some detail and that it
 could be the rose window and he looked at me and said
 'you know, they can't get the glass anymore, you know'
 [laughter]
 ...yes 'the factory is out of operation', he said, 'you know,
 that has been there since the twelfth century'. Anyway, 540
 then...then there was a very important point in the
 discussion when....we had in this office, I had prepared
 a few sets of pages of what I thought a Design Principles
 Document would be. 545
 AMDS: Alright, to show him?
 RJ: To show him. But I had kept it in my bag and I wasn't
 going to show him and make a fool of myself unless I had
 to.
 AMDS: No 550
 RJ: and either I wasn't...either he didn't want to get engaged
 or he didn't quite....I wasn't quite communicating clearly
 enough the idea of principles. I certainly know that the
 principles is a much more of an academic way of looking
 at things than Utzon's way of seeing them, which is more 555
 intuitive. It is no less intellectual – far more intellectual
 – but it is not that sort of eh...that academic, rigorous
 approach which is my approach, so there could have been
 a lack of clarity in my presentation of the idea. Although I
 doubt it...I think he knew exactly what I was talking about. 560
 But he didn't want to indicate
 AMDS: yes, if he knew then he had to say yes or no, I guess
 RJ: and then....and then an important moment in the
 discussion happened when it was clear that the day was
 drawing to an end. I hadn't gotten any further, he was 565
 getting tired and I would have to leave and I'd gotten
 nowhere.
 AMDS: Hmm
 RJ: What I'd got was two days of wonderful discussion

570 – absolute memorable – and if that had been all I'd got
it would still have been the highlight of my life...ehm...so
I was emboldened to say, at this stage he insisted...I
started calling him Mr. Utzon and he was horrified of the
thought, so I said, 'Jorn, I am sad to say that there are
575 many experts on Sydney Opera House and you are not
one of them because you've chosen to not write about the
building, not speak about it. Those that have written and
there are many – who are experts – it's their voice about
their impressions of your ideas that will be on the public
580 record in a hundred years time – they are the experts. The
Design Principles is an opportunity for you to put the real
principles, the real ideas behind the building on paper
in perpetuity so whenever anybody wants to come back
and either look at the building architecturally or alter the
585 building in any way that there is a reference document of
what is behind – what is your ideas behind the building.'
And then he said...then he got more interested and said
'what do you mean by principles, show me an example' and
I pulled out from my briefcase and he flicked through them
590 like this and he is very intense in the discussion and in
looking at them and then he said 'I see...I see, wouldn't it
have been marvellous if the Acropolis would have had such
a document?' [laughter]. And I said 'Absolutely, but what's
more relevant today is that the Opera House gets such a
595 document. And then he decided to go out for dinner. And Lis
rang up somewhere and we trundled down to a restaurant
in Callador and I left him at 11:30 in the evening. I was
exhausted and he was still chatting, you know, and then
we agreed to meet again on the following day and think
600 about the terms of reference and how it might be done and
everything
AMDS: so he'd already agreed at that point
RJ: he'd agreed. And then...then...something I shouldn't be
telling you but an extraordinarily elegant thing happened
605 when...and...when I said to him 'ehm, we have to...I have
to take back...ehm..a proposition to the Government to
appoint you. What is your fee? How do we arrange an
acceptable form of payment?' And he looked at me and
he said....he said....ehm, 'For such an exercise, for such
610 a document there could be two fees. Either I do it for
nothing...' and I said 'No, no, that's no possibility, there is
no expectation. You need to be paid a professional fee' And
then he said, '...or I do it for' and he specified – and I wont
for the record tell you the amount – but he specified a very
615 precise number of dollars, very precise number of dollars.
Not a rounded...
AMDS: got you thinking what it was...
RJ: no, no I knew exactly what it was. That was the in
19...again because I was lucky enough to have read it and
620 remembered it – it was the amount of money that was
owed to him in 1965-dollars or 66-dollars that he lost in the
court-case.
AMDS: Ok!
RJ: Now by this stage it wasn't a huge amount of money
625 because he wasn't considering inflation. And I said to him,
I knew exactly, and I smiled and said 'In the circumstances

I am sure that is the absolutely correct amount of money to
ask'.
AMDS: yes
RJ: And he said, 'I will do the design principles for nothing, 630
I need...in order to do that, I need to draw on work that I've
already done but haven't been paid for'. I said, 'precisely'.
AMDS: yes
RJ: And...so I came back then with this amount of money.
And of course... the amount of money was quite modest... 635
was far more than any bureaucrat would think that you
would pay for any document. So we then had to concoct a
method of structuring the fee so that it looked reasonable
AMDS: [laughter] yes
RJ: so we broke the amount up into several parts. One part 640
was to write the document, modest amount, another was
for the copyright to use the drawings and another one was
for the publishing right to the document. And they all added
up to exactly to this odd amount. And that took...to get it
645 through the bureaucracy here – first of all to get it through
the Trust – that took months! Several months and I was
absolutely distraught and despaired and angry and furious
that those idiots... not to immediately agree to it.
AMDS: Yeah
RJ: And I could see him back there in Mallorca thinking 'this 650
is the test'. It was sufficiently big enough amount of money
to test them but not a ridiculous amount of money that if
they were serious, they would agree to it.
AMDS: yeah
RJ: because the document was worth that amount of 655
money. But it was more money than a bureaucrat could
justify.
AMDS: yes
RJ: and I think he was fully anticipating – not necessarily
fully anticipating but it wouldn't have been a surprise to him 660
if I'd rung him and said 'they wont agree to the money'
AMDS: yes, and then he knew what the situation was
anyhow, I mean, that would have been an indicator of
whether they were serious or not.
RJ: absolutely. And that was what I said to them. 'Here 665
is you... pay him, don't argue! That's...that's....that's the
money you put on the table to indicate your seriousness.'
And it wasn't the money that was...interesting to him it was
the absolute paltry of the amount. Now most....very few
670 people know that story because the amount...well, because
of procedures and all the rest...but the amount I can tell
you because you are in Denmark. But...but...but you see
there was this whole series of little traps, no necessarily
traps but little tests that he was lying out and he does that
675 all the time. Ehm...to test. And it is a method of protecting
himself and Lis is absolutely masterful of doing that as well
and Jan is as well. He [Jørn Utzon] has lived a protected life,
not only by his own wits but by those around him protecting
him. And...ehm...anyhow, the following day we had another
680 fabulous day but I think it was that second day, that started
at ten in the morning and finished 11:30 in the evening,
that was extraordinary.
AMDS: Yes

RJ: Absolutely extraordinary. And the following day was more
 685 about...ehm...it was a half a day or a bit more than half
 a day...was more about 'how do we proceed from here'.
 When the approval was made I went then back again with a
 conditions of engagement which I negotiated with him and
 by this stage he was happy tohe was happy to take my
 690 advise on what should legally be in that document or not in
 that document
 AMDS: ok
 RJ: and then we started the process...in those first meetings
 Jan wasn't involved. I hadn't met Jan at that stage. That first
 695 trip... The second trip I met Jan and then the arrangement
 of how we would proceed...because part of his agreement
 to do the work was very interesting. His agreement was
 that all formal communication through Jan, no...no...direct
 communication to him – other than me – only architect
 700 to architect. No managers to architect. They...the
 management of the house and the project management
 and the engineers and everybody came to Jan. No direct
 communication. And by enlarge there were many attempts
 by many people to circumvent that process and he never
 705 let it happen – nor did Jan. And the only people he met was
 Skrzynski
 AMDS: ok
 RJ: so he met Skrzynski as the chair because the Trust...in
 his mind...the Trust was his client. The client wasn't
 710 necessarily the Premier although the Premier had written a
 letter because the original client was the Trust so he saw in
 the chair of the Trust a symbolic client and he always had
 favourable...eh...attitudes to the Trust. It was when the Trust
 was no longer the client and the client was the Government
 715 - that's when his problems on the house started, you see.
 AMDS: yes
 RJ: So Skrzynski saw him and Roger Wilkins [Director-
 General of The Cabinet Office and NSW Ministry for the
 Arts] the... the...arts...head of the Arts Department, Arts
 720 Ministry, saw him. Later on Gillespie saw him too. But that's
 the long answer to your question.
 AMDS: ah, there were several questions in it
 RJ: But it is sort of an interesting story.
 AMDS: yes it is.
 725 I think we should proceed now to the Gold Book because
 otherwise we won't make it.
 RJ: [skipping through pages of the Golden Book] Yes, I'll
 show you what is going on... [looking at section in Golden
 Book]...you could argue that it is not as simple as his
 730 original proposal where you walked on the plateau all
 the way to the performance but it is far more simple than
 what is there now... so that's the first and the second tier.
 Nothing could be more simple.
 You can see how the beams - the plywood boxbeams
 735 – exactly similar to the original idea. And there were many
 attempt by engineers and project managers and other
 interested parties to do them in any other material than
 this. And all the studies pointed back to this. Because the
 thickness you need for the acoustic insulation is enough
 740 to make it structurally rigid. If you built it in steel, the
 weight of the steel is just going to be added to the weight
 you need – the steel is structurally redundant. And in the
 end, when Arups had done some calculations they proved
 that providing that you could use the stage hoist to lift the
 plywood elements into place, it might take you a month
 to prepare and rigging but you could then hoist the whole
 750 thing in a month.
 AMDS: A month!
 RJ: Yes that is quite quick. [looking at a rendering of the
 Opera Theatre]
 AMDS: It seems that you are not quite sure about the over-
 pit reflector
 755 RJ: Oh, that's not final yet. Because it is not in here [it is not
 in the final rendering of the Opera Theatre] but it is here. He
 doesn't mind the idea of a reflector. Originally you can see
 in some of those models [pointing to polystyrene models in
 the room] that we were struggling to incorporate them into
 the ceiling so that...
 AMDS: and then you lost a lot of the volume
 RJ: yes, too much volume. And this is where you needed
 the volume to build up the reverberance. And he accepted
 765 that and he was then quite comfortable with putting in a
 reflector. But he said that the reflector should take on the
 appearance of a technical equipment – and take the shape
 that it needed for acoustic requirements. And probably be
 painted out dark and not be seen as a part of the ceiling.
 770 Arups haven't done yet the final fine-tuning of the model
 AMDS: ok, so that'll be detailed in a next stage.
 RJ: yes.
 AMDS: Thank you very much. I took a bit too much time, I'm
 sorry
 775 RJ: Don't worry. Thank you.

| | |
|--|--|
| Interviewee: Matt Morel, project architect on the Sydney Opera House project, employee of Johnson Pilton Walker | |
| Interviewer: Anne Marie Due Schmidt | |
| Date: February 22 2005 | |
| 5 | Location: Meeting room Johnson Pilton Walker |
| Notes: The interview focuses on the Design Development – an internal document on the project – the page numbers refers to this document. | |
| 10 | AMDS: This design study of course starts at a certain level. For instance the first sketch by Jan already implies that you'd have to dig into the podium, but what happened before that? |
| 15 | MM: Yes, my memory is not great on dates but I think it was six months or a year before the sketch when we completed the ... I can't remember exactly what it was called but the 'pre-pre-concept'. So really when the completion of the benchmarking where the deficiency of the opera theatre |
| 20 | in its entirety was put out and the question was raised 'well, surely if we close down the opera theatre to make the orchestra pit bigger but no changes to the surrounding, it would be dissapointing'. So we did a very short study with, not a complete consultant team, but with quite a bit |
| 25 | of consultant advise. We were working mainly with the acoustics and the theatre adviser and some structural input. And together we said, look what are our possibilities. We examined what we could do and we came clear early that to achieve more volume in the auditorium you couldn't |
| 30 | go up, you couldn't go to the sides, you couldn't go north so you had to go down. It became a question of how far down. We did a couple of different studies with different levels, with what could be achieved. |
| 35 | We also looked at how far could you take the existing auditorium, what improvements could we make. |
| AMDS: Like Richard was talking about the last time with painting and so on? | |
| MM: Yes but we were doing all sorts of different studies and we also talked about completely rebuilding the whole | |
| 40 | theatre at its existing level. |
| AMDS: Ok. | |
| You are talking about the seat numbers. What seat number is actually aimed at in this study? | |
| 45 | MM: In this study? Well 1650 but the seat number has a number of conditions to it. Is it the seat number with a normal size pit because the pits, these days, normally has a flexible size, and in some cases in some of the venues used for conferences or contemporary dance, you don't need a pit at all. |
| 50 | AMDS: Ok, so you can cover it up. |
| MM: Yes it gives the opportunity to add another hundred seats. | |
| AMDS: Ok, so around 1650. | |
| MM: Yes, we've got a range around 1650, yes. | |
| 55 | AMDS: You were writing that 'the curve of the ceiling has to be flattened' and Richard was also talking about it the last time that this was due to... or that Arups was always |
| talking about having a more flat ceiling. So at this stage the acousticians had already been introduced to the project. | |
| MM: Yes | |
| AMDS: It's just because in the text it doesn't say whether it is something you think or it's something the acousticians think. | |
| MM: Right. The acousticians were involved in the pre-concept study. | |
| AMDS: Yes, even before this study, ok. | |
| MM: And even before that they prepared the benchmarking study. Ok, that was even before. And why it had to be flattened... from memory I think the acousticians were concerned that the curve created too much of a dispersal of the sound rather than what would happen with a flat ceiling. So you can see that so much of the curve would not be helping the audience at all. | |
| AMDS: And this part of it [circled on page 4] is that what you call the wall-ceiling connection or is that more in the sides? | |
| MM: I think we were more considering the sidewalls. We knew we needed to look into how the seating should be arrange in these side areas and how these side wall, which are very important for acoustic reflections, into the seating areas, how they would relate to the ceiling because it was obvious that it could not just be ribbon going down because, you can imagine if you have the ribbon going straight down you'd get an area of the wall reflecting the sound right back at the stage. | |
| AMDS: Yes, because in the original he had ribbons exactly pointing that way. | |
| And the shifting of the radial option is also due to reflections, right? | |
| MM: What do you mean when you say radials? | |
| AMDS: I mean this kind of configuration where you have one point on the stage and then shift it backwards. I looked at how the reflections would in this option go further back into the hall while here it is directed inwards, but I don't know whether that is the reason for doing it? | |
| MM: Well, even here the side wall plan geometry is quite independent of... well not independent, there are sections that reflect the radial set-out but more and more we've minimized the length of those actual radial parts of the side wall but they are still a part of the expression and add to the sense in the of the radial geometry organizing the room. | |
| AMDS: So you wanted to maintain the expression of it but not taking it as far as it was in the original | |
| MM: Yes, we need to defer to the acoustical requirements. And I think a good balance has been achieved. | |
| AMDS: Are they [the halls from the benchmark study] approximately the same number of seats as this hall? | |
| MM: Approximately within 200 seats. The Scala might be a bit more. It has a much flatter stalls. But this was where we were in March, our stalls configuration has changed. | |
| AMDS: That is actually one of my questions, why is that? Is it to maintain what is there now, or? | |
| MM: That has to do with the entrance to the stalls and the decision that it must be from the podium and the | |

- 115 stage must be on a certain level. Acoustically I think, well obviously if you drop the first row in the stalls you get slightly more volume but that, I think, wasn't really the goal. I think they find that the flatter stalls would allow the sound to travel back further in the hall. It makes sense. So we did
- 120 that for a number of rows and then connected it back to the rest of the stalls.
- The existing rows in the hall are quite steep and people in the stalls have very good sight lines. So there was a concern that we should at provide a sense of continuity
- 125 where they still would get reasonable good sight lines.
- AMDS: Of course they would be disappointed if it reopened and you couldn't see a thing. It says that the stage has dropped -10 [at page 13]. Is that foot?
- MM: Stage edge at x=-10
- 130 AMDS: It that three meters?
- MM: What you need to understand is that the original opera theatre is arranged on three axis around a centre point and the y-axis, which is normally the centre of the stage, and then an x axis and a z-axis that was the height. So the stage
- 135 edge at x=10 means that we are being ten feet back. Does that make any sense?
- AMDS: Mhh, so you are telling me that it's not that it is not dropped down but backed out.
- MM: It's dropped and...
- 140 AMDS: ...and put back?
- MM: Well, I can't remember of the top of my head where the existing stage edge is. I think it is somewhere around minus 7 foot or minus 10 foot. In the x-direction.
- AMDS: Ok.
- 145 Well, perhaps this is just due to my lack of knowledge on operas but what is that part [page 8], what do you do in that space?
- MM: We hadn't resolved what we'd do in that space at that stage, but now I could imagine a number of things it could
- 150 be used for. But at that point I think we were working on a set of parameters that related to where the walls and the reflecting surfaces should be in the auditorium and one parameter was that within that zone relative to somebody on the stage, with the orchestra here, there should be
- 155 a couple of parallel, close to parallel, walls at a certain distance apart. But we needed to this wide here [in the stalls] to get enough seats in the auditoria. We hadn't really thought about what that area could be used for.
- AMDS: Ok, I thought it was the other way around, that you
- 160 wanted these spaces.
- MM: No, it was more from the inside.
- AMDS: Ok, and then you write, that was probably what we talked about before that 'lowering stalls create fundamental problems in circulation'; you'd have to go below the podium
- 165 and that is what you didn't want. At the moment you walk in from behind, right, but there is a ramp here, so you walk down some distance or?
- MM: Well, you come from the southern foyer and you either choose to rise up that existing podium stair or you would take this ramp through to the existing northern foyer.
- 170 AMDS: But ramp..?
- MM: It's very shallow
- AMDS: Ok, I was wondering because I couldn't see any ramp.
- MM: It does ramp, but only 300mm. Then at this level again
- 175 you either choose to continue up or you pass through a slot in the middle of that stair to the northern foyer. And interestingly that slot was part of the original design and structurally is there now. We don't need to do any structural demolition. It is covered up at the moment with the stair.
- 180 And then of course you come up the podium and into the second tier. Yes, in this scheme it seemed unacceptable to go so much further down. You are not to go away from the existing podium foyer areas before you go into the auditoria. It was actually a part of the Utzon Design Principles that
- 185 Richard mentioned last week. It specifically speaks about that you should be on the podium right up until you go into the auditorium.
- AMDS: Yes it is very logical as it is at the moment. There is a gap of course because there were some work done in Denmark with Jan and Jorn, I guess, and I was wondering whether you could... were you there?
- MM: some of the time.
- AMDS: Ok, because, who was there? Was it also the
- 190 acousticians, construction guys or?
- 195 MM: The acoustician and theatre planners were in Denmark at Augusts working session with Jan and ourselves.
- AMDS: Ok.
- MM: After which Jan, Jorn and I took the outcome of those
- 200 working sessions and did a few further days and then Jan, Jorn and Richard had some very productive days after the working sessions.
- AMDS: This is some of the last things in this document and I was wondering, this problem about the curve of the ceiling
- 205 is that not still present [page 6 and 18]?
- MM: A lot of the sections that would cause problems are, especially in the centre part of the ceiling, are actually being used as lighting slots, which is a happy way of taking
- 210 away the problem.
- AMDS: I read somewhere that in the original proposal there was just a hole where the lighting was fixed, that it wasn't covered with glass or anything, is that the case now as well?
- MM: Yes, the forward positions are not covered with glass but the follow spot in the rear of the room will be glazed but
- 215 the glass will be in an orientation that does not cause any problems.
- AMDS: Then I have some questions about how you collaborate with Arup's which of course is very interesting to me. When you work with them...
- 220 MM: Arup Acoustics?
- AMDS: Yes. Do you sit down and have meetings or do you send material back and forth or...
- MM: Let me try and explain... As its working; starting with the workshops where the consultant from the UK would
- 225 come here for a week or ten days and perhaps Jan would be here also. Or we would go to UK or to Denmark and spend some days working together – they are quite intensive days.

230 Then regularly we have video conferences where we discuss work in progress, discuss the different drawings and works and comments that have been going back and forth via email or telephone calls. Of course the consultants working here in Sydney or Melbourne, we have regular meetings with. Rob Harris the principal involved in the project, but

235 there are a number of key people involved in the project at Arup Acoustics based in Sydney or Melbourne so often it's enough to call somebody there and say 'what do you think about this' and they can give us an answer or they'll discuss it with Rob.

240 AMDS: I spoke briefly to Jason at Arup Acoustics
MM: Is he telling the same story?
AMDS: Ahh, kind of. It was very briefly, but he actually said that you and him were doing the work. And that you'd often discuss things and then take it back to where came from. I

245 don't know whether that's right?
MM: I think that's only natural that on large projects like this there are some people directing the work and have the conceptual ideas and there is a lot of work to push those through and resolve them and it takes people like Jason and I to work it through.

250 AMDS: It seems like Arups – based only on what I can see in these papers and what Richard said the last time – often suggested that you'd change the form for instance of the ceiling or the side walls or whatever but how would they suggest that – is it by diagrams like these [pointing to 3d-diagrams of sound pressure from Odeon] or would they draw on it or how would they do that?... This is really nitty-gritty but...

255 MM: No, no, it's fine. More often than not, they would demonstrate to us on our drawings or on our model what is not working so far and that'swe would then say 'ok, if we do this or do that or some other thing, would that help?' And they'd go 'no', and we'd go 'then if we'd do this or do that would that help?' And they'd say 'Yeah, that might be better'. So that's one way that it has happened and then we'd go and change our drawings and offer it to them again to comment on. Usually there'll be a whole range of things that we need to develop and for each of those thing we'd put forward some discussions or options on how we might improve that. And that might take six weeks or two weeks to solve all that and then give it back to them and say 'right what do you think now'. On other occasions they would point out what needs improvement and we'd say 'ok, you correspond and tell us what you want' and we'd

270 either absorb it or come half way ... Sometimes we'd send drawings back and forth between us. Other times they take – do you know about the Odeon modelling software?
AMDS: Yes
MM: So they'd take CAD models and translate them into

280 their Odeon-software and I think on a number of occasions they've made quite broad changes within the model themselves. Quite brutal changes – super flat ceiling or taking out all the side balconies - just to see how sensitive the design was. Maybe if we'd make a flat ceiling we'd still

285 have all the same problems.

AMDS: Ok, so then the problem is not coming from there. I haven't worked with Odeon but I've worked with a similar program where you can auralise sound, that means that you can hear it. Have you used that as well; as a means of communication?

290 MM: Not as a means of communication. I understand that Arup Acoustic has – in their various stages of the study – made some auralisations for their own analysis but we haven't heard them. AMDS: Ok
MM: But I expect that in the coming stage of design we'll be using them.

295 AMDS: They are also building a room for it in Melbourne, I think.
There are a few more questions. This is more a general one. How is your attitude towards all this with bringing Utzon back and going back to an 'old idea'

300 MM: Well, I think to me, personally, I think the opportunity to work with Jan and Jorn on this project is wonderful. I am not sure what you mean by going back to an 'old' idea, are you referring to the radial geometry?
AMDS: Yes
MM: Ehm, I don't know but I think it's a fantastic idea and I think it has... it offers a great architectural auditorium and in the sense that nobody has ever developed it and in the sense that it wasn't completely resolved in the 1950ies this is an opportunity to extend that idea rather than go back to an 'old idea'. I think again that you should question Richard on that.

310 AMDS: But I think also it is very good to hear your opinion because you have been very much involved in the work actually being carried out. You might have been frustrated about 'why should we do this at all, wouldn't it be better with the knowledge we have in acoustics, I mean we are not in the 50ties, 60ties now, why do we take an idea from back then?'
MM: I think that the architecture really should lead the design and the acoustics sure moves ahead and they have wonderful tools now to analyse it – it seems so to me – so we can take this idea and work out how to make it the best acoustically and again and again we are hearing that it can be very good acoustically. I think that this idea is in great harmony with the whole building, like I said last week, the principles that guided the building in the first place.

320
325

Interviewee: Jan Utzon, son and partner of Jørn Utzon
Interviewer: Anne Marie Due Schmidt
Date: April 26, 2006

Location: Telephone interview between JU in Hellebæk,

5 Denmark and AMDS in Aalborg, Denmark.

Notes: Interview ends abruptly because the telephone was disconnected.

10 JU: Jan Utzon.

AMDS: Hi, this is Anne Marie. Is this a better time?

JU: Now is fine by me.

AMDS: Great. Okay, let us give it a go. Just a brief

introduction: I am doing a PhD on tectonic practice, as I call
15 it, and one of the cases I am using is your renovation of the
Opera House, especially the Opera Theatre, so that is what
I would like you to tell me about, and also a bit of general
background information on you and your father and so on.
So that is what is on the carpet. To begin with: How would
20 you describe yourself as a professional – what is the most
important thing for you in your work?

JU: Obviously, the most important thing for me as an
architect is to try to solve a task, the physical task of
erecting a house somewhere. One that is suited to the
25 client's requests and to the area in which it is located, its
surroundings and so on. If it does, there is a good chance
that it will become a fairly good building, which is both
pleasing and useful.

AMDS: Ok, what about the building process itself? Is that
30 also important to you? For example, your father was very
involved in the Sydney Opera House, in the construction
itself.

JU: Yes, he was. Because, obviously, when you build
"normally", so to speak, there are some traditional
35 construction methods that you can use, which makes
it a fairly straightforward matter because the workmen
and everybody else are acquainted with them. But the
construction of the Opera House produced a new set of
questions, and people were kind of groping for a solution.
40 There was a lot of trial and error. Here, my father's sense
of practicality - his childhood with the shipyard, ship design
and so on enabled him to perceive things from different
perspectives and not so much in terms of traditional
materials, but in other ways – enabled him to sweep
45 through alternative materials and find solutions, which,
at first, others did not find very sensible. In hindsight, of
course, they were just that.

AMDS: You mentioned that there is a chance for a fairly
successful building if you can live up to the demands of
50 both the client and the place itself. But what is it, to you,
which really characterises the successful building? You also
speak of the user. What is the main issue?

JU: I think that when I get to that point it is if I feel
good about the building, and what I have designed and
55 subsequently built the way I feel it should be done, then
that is the most important thing to me. If everybody else
feels the same way that is even better, but those two

things are not always the same. Sometimes, most people
think it is quite the success, whereas I disagree because I
have had to make certain compromises that I am not too
60 happy about. There are some buildings... If you are asked to
exhibit some of your buildings, you are more than happy to
display some of them, while you avoid others, because you
do not find them to be anything out of the ordinary. Thus,
I have contributed to some buildings that to my mind are
65 more successful than others. This has to do with the fact
that we, architects, are somewhat different from painters,
writers or composers. We do not work on our own. We do
not produce a work that posterity can enjoy or dismiss. We
achieve something as a part of a large group of people.
70 It is a team effort, which means that a given house is not
solely the work of the architect. It is also the work of the
constructional engineer, the client and the workmen. It
also hinges on how well they have done their jobs. It is
the work of the authorities who have decided on various
75 issues around the place, and of course it also has to do
with economy. It has to do with a lot of things. Perhaps the
economical part is not all that interesting since the creation
of something beautiful can be achieved for a very small
amount of money.
80

AMDS: Yes, okay. Picking up on that angle, how do you rate
the Opera Theatre, the design project that you have just
completed?

JU: When my father built the Opera House, the interior was
a part of the whole that was the Opera House. Then new
85 architects were involved, and the new client wanted the
interior changed to suit other functions. So, the end result
was quite different from the original idea. Later, it has
turned out that this was not quite suitable. There was too
much crammed into the place. So, we have come up with a
90 new project on how to solve that problem, if they are willing
to spend the money required to tear out an entire hall and
then rebuild it. Nevertheless, we have shown a way of doing
so, which is in accord with how it used to be. It is not the
same – the circumstances are different today – but the
95 impression you get from entering the hall is essentially the
same. The same goes for those who work there. In that way,
it is similar to the original. But so far it is all just theoretical,
and it is only after it has been built that you can judge
whether or not it is a success, which, however, we architects
100 are sure that it is going to be.

AMDS: So, essentially you want to reserve the right to wait
until it is there before you decide whether it is a success or
not. But as a sketch project, would you at this point regard
it as a success?
105

JU: Yes, because plans and illustrations can never give you
the same impression of a building as the finished product.
When you can be inside it, touch its walls, sit in the chairs
and so on. A drawing simply is not the same. People do not
buy a car if they have only seen a sketch of it, right. First,
110 they get some fine brochures, and then they go and have
a look at it, get into and out of it, go for a drive in it. In that
way you are much more certain that it is what you want at
the right price. When it comes to houses, you first buy a

115 sketched idea, which is subsequently adapted to a working drawing, and finally turns into a house. As a customer, though, you are a bit adrift regarding 'what you'll get' until it is actually there.

AMDS: Yes, there is no test-building, which you can look at and see for yourself.

120 JU: No, but when building apartment houses abroad, you often construct a test-apartment somewhere so that people can come in and get a feel for it. Then you sell the apartments in the block. There is no such tradition in Denmark yet – it has always been based on sketches and prospects – but it is on the rise.

125 AMDS: Often, that is how it has to be. You mentioned that there were a lot of similarities between the original proposal from the 1960s and the one you are making now. But many things have changed. The original was largely governed by a geometrical idea of how the arches in the ceiling should be, which, I suppose, had a lot to do with how plywood was manufactured. There are other options now, so why retain it when it is no longer tied to existing manufacturing technology?

130 JU: It was not tied to manufacturing technology. It was the other way around. The ceiling itself and the convex arches were the result of a co-operation with German acousticians, so our primary concern were the acoustics. Of course, that was what we could fit under those roof shells; that was also a restriction. It was made simultaneously, but developed apart, and the solution to the shells and how they were built was done and dusted before we had decided on the ceiling – the acoustic ceiling. We knew approximately what we wanted, but it was not fine-tuned until the rest of the building was in progress. This means that there was an adaptation of it, which made those spheres, which they are across, in order to get all the construction parts they wanted, or, my father wanted a geometry that made it easy for everybody, also the workmen, and which made it easy to produce. So, if you could put all of that into a common geometry, it was an easy decision. It is like the beams of a ship, where you have a sectional elevation where you put in some iron frames, beams, which you mount, and there really are no two ways about it, they are just mounted. Then you fit in the side plating, and you have the form of the ship. Instead of having to measure height, length and width each and every time you put in a plaster-board, you have these forms, which, when combined, yield a result, and that is the hall. The combination of acoustics and moulding the construction itself into a geometry, which made it easy, was very interesting to my father. It went well back then. Now, we have been through the same procedures once more with new acousticians, who also began by saying that the hall should be rectangular, well-knowing that that is impossible.

165 Since the Opera House is the way that it is, you must adapt to that form. Then we went through the discussions of the old ceiling. Fortunately, we had the old models, which they tested, and found that the acoustics are simply the best. So, they have also reached the conclusion that this system works. Then there is the construction. Now, like then, they

said, 'let's make a steel skeleton, and then cover it with plywood.' Plywood, however, has to be fairly thick. In order to possess the right acoustic qualities and reflect the sound back at the audience, it has to be almost 10 centimetres. Then we found out that the steel was superfluous as plywood of such thickness can support itself. So, we agreed that the original idea with the big plywood pipes was spot on, and so we were back where they left off in the 1960s.

175 AMDS: And how about production of plywood pipes today? The old plywood factory is dark and deserted.

180 JU: But that does not really have anything to do with it. The plywood factory went on to produce regular plywood when its founder died. Until then, they had made full-sized railway carriages from one piece of plywood, but then people thought it was easier to make a standard plate measuring 1.20x2.40, like they do all over the world. I am not sure, but I do not think the factory exists anymore. But that is okay; we just took it from there. That plywood construction is quite possible with the plywood available today. The form, the geometry, the weight, it is still the same.

185 AMDS: Returning to your co-operation with the acousticians, why was Arup's chosen for that assignment?

190 JU: In the 1960s, Arup's was known for a few specific engineering disciplines. Since then they have expanded their horizons to a range of other engineering fields and have become a large company. It began with the Opera House in Australia. Since then they have expanded, and they have had many other assignments. I do not know how the engineers do it, but they are really good at collaborating with other companies, and all of a sudden they have an engineering firm, a consultancy with several different fields of expertise; the environment, roads, dams, harbours, buildings, you name it. Some of them employ acousticians. Then they know how to do that too. Apparently, Arup's have done a good job in many theatres in Europe and the United States, so when the Opera House needed acousticians they had a handful in mind, and they asked 'how about you' – we were not involved – and they picked two companies for the two auditoriums, the Opera Theatre and the Concert Hall. They chose a Japanese one for the Concert Hall, and Arup's for The Opera Theatre. Then we said, 'that's fine by us. If they possess the know-how, which apparently they do, they must be good.' And so we worked with them. They also worked on the Opera House in Copenhagen, you know.

205 AMDS: Yes.

210 JU: So we have no problem whatsoever working with them. Our client chose the acousticians.

215 AMDS: How would you describe them? You say they had the know-how to solve that assignment, but how were they to work with?

220 JU: Well, I only know the specific people that I worked with, and they were nice and seemingly competent people. Moreover, they knew how to listen to criteria other than their own. Having perfect acoustics is one thing, but it also had to fit in with the conditions at the Opera House, which cannot be changed. We can only do so much within the given framework. They understood that and made some

225

computer models. In the old days, they made models large enough to stand in. Now it is done on a computer. You use
230 this software, which you can ask 'if we do this with the surface, how will it sound?' The tools have improved. They have become easier to work with.

AMDS: About those tools. Does it affect you as an architect? Obviously you were not there in the 60s, but maybe your
235 father noticed a change?

JU: It is easier, perhaps, to get it right with the tools available today. There were many acousticians and experts back then, and one of the most famous; an American who wrote a lot on acoustics and who also constructed many,
240 acoustically speaking, useless halls, so apparently there was an element of luck back then. Then along came these people who developed a technique for measuring using a model. Hopefully, the results would still be accurate in full size. Cremer Gabler, this German company, was actually
245 really good at it. Using electronic listening equipment, of course not quite as sophisticated as it is today, on a large-scale model they were able to determine how it would end up sounding, and then adjust it accordingly. Subsequently, their work on several halls in Germany has
250 proved them right. So, the acoustics would still have been good if it was built back then. Today, there is – you know, people are always inventing and trying to develop new ideas, so there has been a whole lot of development over the 30 intervening years, and with the computerisation of
255 everything we do, and the development of new software, which...how shall I put it...they have plotted in all the known halls and found out precisely how they react, and then they have fine tuned their computer program in order to make it fit with the halls they already knew. And so you can
260 continue working with that program and predict how other forms will end up sounding. It is one of those tools that are undergoing a perpetual development At present we are at a given point in this development, right, but it goes without saying that in 10 or 20 years, its predictions will be even
265 more accurate. Finally, there is the matter of opinion. One conductor might love a particular hall, whereas another does not particularly care for it. Then there is the audience, which finds one hall very suitable for listening to music, whereas the same music does not sound particularly well in another. In the end, it all comes down to subjective
270 evaluation.

AMDS: Yes, of course.

JU: As a conductor once told my father, each time you come to a new hall it is like a new instrument and you have to
275 listen to it, and then use the orchestra to make the most of that particular hall. Therefore, the same music is different from one place to another. That is part of the excitement. If everything sounded the same it would all be over fairly quickly. It would be uninteresting to work with. But the fact
280 that each hall is different, and there is this big orchestra that has to be pulled together, 'okay, we need more bass', then that is adjusted, or 'we need more violins...' Thereby, a given musical piece is interpreted differently in different places by different conductors, and different audiences are

treated to different experiences. It is that kind of renewal, which keeps me interested. 285

AMDS: How about the acousticians, do they share that view, because it all has to do with this subjective experience, where their task is to recreate the subjective experiences in their computer programs? 290

JU: What they do is to make the sound that you experience in the hall clear and resonant all over the hall, so it does not make a big difference where in the hall you are seated. That, of course, is not entirely possible. The sound on the third row is bound to be different from the sound on row 25, 295 but the goal is to produce good sound in the entire hall. It will never be entirely identical, but in some halls either the high or the low pitched sounds disappear in some places. That is the kind of thing that simply must not be allowed to happen. Preferably, everyone should witness a resonant and complete acoustic pattern anywhere in the hall. That is their primary job. Also, the musicians must be able to hear what they are playing; unlike at the Albert Hall in London where the time it takes for a tone to return is simply so long because the reflective surfaces are so far removed from the musicians. There is a delay on everything they do, which can be quite testing for the musicians. 300

AMDS: Yes, it is quite difficult to hear one self.

JU: Nevertheless, the Albert Hall has other qualities that make up for the sound. It has a lot of festivities, which the audience loves. 310

AMDS: Yes, it is outweighed by other issues. Throughout your work with the acousticians, how were they, or were they not, able to support your work with the modelling? Can you give a few examples? 315

JU: ...We guessed at how it might be done, and then they plotted our sketches into that computer technology and said, 'try to turn those surfaces', and now we have boiled it down to a few specific surfaces that can be turned. Then we have tried to turn them slightly one way, then the other, thereby nudging the ceiling and the position and angles of the side walls to where we got the best overall sound. Kind of like if you imagine a lamp on the floor and you have a lot of mirrors on one wall that reflect the light onto the opposite wall. The mirrors are mounted at an angle so you can turn them slightly – then you can place them at an angle, which reflects the light back at all the other walls. That is what we have done with the ceiling and the side walls. We have turned them so the reflected sound is as evenly distributed as possible in the entire room. 320

AMDS: That is a very good analogy. It is a bit late in the process, but have they been good at supporting you early in the process, where you do not have a design and have to figure out where you are actually going? Pre-modelling. 325

JU: We had the limitation that the house was already there. If the house was not there, and we had started from scratch, the hall would probably have ended up looking different. Presently, the acoustic preference when it comes to halls is more or less the shoebox-shape, but that was not possible. Then you can aim at – maybe not aim at it, but then you can look at something else that might turn 330

335

340

out just as well. Then there are some cases – elsewhere that is – where it is simply hopeless, but you can always say, ‘okay, then we’ll have to reduce the room, so we can give it a shape that works’. But we had an idea of what we wanted from the beginning, and they tested it with their instruments to see if it was a good idea. Eventually, after a bit of push and pull, we found out that it was. When we built the Esbjerg Musikhus, the acoustician, Niels Jordan, was there from the beginning, and the form of the room was determined by the acousticians and the fact that they wanted to be able to remove the seats from the halls on one of those telescope-stands, and a rectangular shape was best for the seats. Consequently, his input contributed towards the hall getting that specific shape.

AMDS: I did not know that Jordan had worked in Esbjerg. His father worked with your father.

JU: Yes, in Australia; yes he did.

AMDS: According to some of the documents it seems they got quite angry with each other and quite frustrated with their working relationship.

JU: I do not think they were angry with each other, but I think my father found out that the German company, Cremer & Gabler, had developed a technique, which was useful in connection with the very complex halls in Sydney, and therefore he consulted them too. Jordan was still there.

AMDS: Yes, he consulted all along, yes, okay.

JU: My father needed someone with a better understanding of irregular spaces, whereas Jordan was more old-school, which, one might say, is also presently applicable with that shoebox-shape.

AMDS: Yes that has been tried and tested, and we all know that it works.

JU: Yes, we know from experience that it works. The hall in the Odd Fellow mansion is certainly a very good concert hall to which Danish acousticians always used to point, but then the problem arises that when a hall for an audience of about 1000 – 1100, but when it exceeds that, when it starts to approach a couple of thousand, 3000, then it starts to become critical.

AMDS: Yes and the hall in Sydney is a large one; about 1500, right?

JU: Yes it is, around 1100-1200 seats that are actually usable. There are quite a few, from where you can not hear or see a thing.

AMDS: You are speaking about the current hall, of course. I was thinking about your sketch.

JU: Oh, Yes. Well, what we have done is that we have lowered the floor in order to get the volume that we need, which also means that we will be able to put in one more balcony row, increasing the size of the audience, which they are very keen on doing down there to around 1700. If you then cover the orchestra pit – Sometimes they do have events where a band is not required – you could end up at about 2000.

AMDS: Okay, that figure is higher than anything I have heard of before.

JU: It is an estimate.

AMDS: Obviously it is going to depend on the size of the seats. I have a question to follow up on Jordan. I have researched the church in Bagsværd, but I have been unable to determine whether he was the acoustician there?

JU: I actually do not know, I do not remember. I cannot recall whether there was an acoustician involved. I think my father trusted the convex surfaces, which he had...learnt that they were really good in Australia, he could use them in Bagsværd as well. We came home from Sydney in 1966, and he was asked to draw Bagsværd in 1969, so it was only a few years later, and in a way a continuation of the same ideas, but whether or not he had an acoustician – I really do not remember that.

AMDS: I was just thinking that he might have received advice from Jordan, but in the records that I have seen, there are no references to any acoustician.

JU: It is quite possible, but I attended Architectural School back then, and I was not involved until the inside finish, where I was involved with making furniture, walls, the altar and so on, but I was not involved with the actual building.

AMDS: Alright. About your co-operation with these consultants – do you perceive any risk in including consultants too soon, the focus, for example, of the architectural modelling might shift, or do you think they should be involved as soon as possible?

JU: I think it is fine to get them involved as soon as possible, but that hinges on the architect knowing exactly what he or she wants, because the consultants could well make things run inconveniently one way or the other. Naturally, they are very interested in their own field of expertise. I remember in Kuwait when we built the National Assembly, we had a Swiss consultant who had to do with drains and sewers. At a certain point, the meetings developed in such a way that he was the only one speaking and he was the only important person until my father said, ‘Enough, pal. You’re a sewer-engineer, and that’s fine, but we’re the ones who make the decisions here.’ He simply took up all the available space with his huge interest in and knowledge of those things. It just was not all that important to the rest of us. So, it is important to use the consultants, but it is also important to know what it is that you want, and that there is a high degree of control about the entire process, because there is no boundary as to how good a job each consultant individually wants to do, and then you, as the architect, must step forward and say ‘that’s fine, we might just be able to do so and so,’ but it is possible that ‘we just can’t afford that,’ or ‘not interested right now,’ or ‘great, we’ll do just that,’ or whatever you would say in a given situation, right.

AMDS: So it is up to the architect to decide which way to go?

JU: Not necessarily, but that is the way we have chosen to work. Some buildings come into being through huge collaborations and that also works, but then the connecting thread is sometimes missing, so to speak, if everything is reeling. That is to say, if everything receives equal priority, if all rooms are created to be equally interesting,

they also become equally uninteresting. If all colours are supposed to be equally interesting, they also become equally uninteresting. There has to be contrast. There has to be a sequence, which makes it interesting to walk through a building. The story you are telling... some books are incredibly dull in spite of a fast-paced story, and then there are some books that contain some very interesting passages interspersed with some more peaceful passages. The same goes for music, and also architecture – at least in our view. We all know those anonymous concrete blocks that were later upgraded with tinplates, but nobody appreciates those unending residential buildings with bicycle chains at the bottom. Somewhere along the line something needs to happen.

AMDS: If you were to relate the connecting thread of the sketch project you have made for the Opera Theatre, how would you describe it?

JU: Back in the day, it was my father's idea that people should come from the humdrum of everyday life with all the joys and sorrows that entails knowing that they were coming to the Opera House for a treat. That thought alone sets the mood for something out of the ordinary. And when you get there and enter the lobby where you meet friends and acquaintances, you are even further removed from the ordinary. Then you enter the hall and the festive mood increases, and when the performance begins that is the icing on the cake that is the sequence of sensations, which began when you left your home or the office and culminated with the performance. That is why the hall must be – obviously acoustically well functioning, you have to be able to see what is going on, and it must work from many different angles – but it must also be a festive hall, a room which you look forward to entering and being in. A room, which sets the mood for something in excess of normal everyday life. The present hall does not have that extra something, because they did what they did everywhere in the 60s. They painted it black, which means that when you get in there and the lights go out you... you just hang there, in the room, not knowing what is up and what is down, whereas the old stage at The Royal Danish Theatre has gold and glitter, small angels, crystal chandeliers, red velvet seats and well-dressed people wearing jewellery and so on. It all contributes to the festive spirit, even though some might not like it for being constructed – it adds something special, which you do not get from sitting in a black room where you cannot see a thing. But it is a different outlook from the one that appeared in the 60s and 70s when everything had to be black so the people in charge of onstage events were free to do whatever they pleased.

AMDS: So that everybody's attention was directed at the stage and nowhere else.

JU: Exactly. But, if you want to experience it on your own, you might as well stay at home and watch TV. Whereas if you go to the theatre, you do so in order to experience it with others, it is an experience that you share with others. You see how other people react, you hear their reactions, and you meet up with them before the show, during the break, and after the show. Consequently, you are part of a larger experience; one that you do not get from going to the cinema or staying at home watching TV. That is why the room itself should also contribute to the mood, and not solely in terms of acoustics or how comfortable the seats are, but also the room itself, the colours and the way you see the rest of the audience. So, if seated on straight rows, people do not see each other as well as they do on rows that curve and they can see everybody if you look to the sides. And of course, opinions differ, and some would think that a cinema where you have plenty of room to stretch your legs is just great, but others would prefer that in a theatre there is not supposed to be too much space between the seats, because it is supposed to be a shared experience. The intensity is important too, and the further people are seated from one another the further they are removed from the stage, and the mimic facial expressions tend to suffer if you are more than 25-26 meters removed from where it is happening, so you do need to be fairly close to the actors if you want full value for your money.

AMDS: Apart from the acousticians, you have obviously also co-operated with others, which I would like to talk about. There has also been a joint effort between the architects – you, your father, Richard Johnson you all worked together in Australia. How did you organise that?

JU: Yes, it was because the people at the Opera House wanted my father back as the architect for the conversions and proposals for changes that were to be made. They have seen that it is my father's work that makes the building so special and attractive to its visitors. What the other architects have done, the interior, is not the attraction, even though that is where people go to see the shows. The iconic function, which they themselves have participated in creating for the Opera House, is part of my father's work. And they would like some of that to rub off on some of the new additions. Then, since we live in far-away Denmark where our office is also located, they have gotten an architect – a local architect – to take care of practicalities. So, our present work down there consists of my father, the boss who is in charge of providing the ideas, and I, head of the office, are located in Denmark, and I travel back and forth, whereas the main work force is in Australia. If you compare it to an office, some of the employees just live some way away, a bit like if we had an office in Copenhagen and someone lived in Hellebæk and Helsingør and then drove to and from work.

AMDS: And some are at the office every day, and some are not.

JU: It works well, and we have an excellent partnership with Richard Jones' office, a partnership which has lasted almost eight years.

AMDS: Yes. So what is the current status for the project? The last time I spoke with Richard Jones it was at a standstill, waiting for funds.

JU: Yes, well, it is a relatively extensive project and some things at the Opera – the Opera Theatre as they call it – are old and worn. The air-conditioning, various other things,

570 the stage, facilities for the orchestra among other things
are quite hopeless, and they want to change that, but they
also realise that it is difficult to patch up, because it never
amounts to more than just patching up, and then they say,
'okay, here's another proposal for improvements, but it
575 costs a lot of money and we can't afford it right now, but if
at some point we can afford to do something really good,
then we know just how to do it.' But it is not certain that it
will happen in our lifetime.

Interviewee: Andrew Nicol, Director Arup Acoustics
Australasia [A]
Interviewer: Anne Marie Due Schmidt
Date: April 05 2005
Location: Meeting room in Arup Acoustic, Sydney Office
Notes: 10 lines removed on request from interviewee

AMDS: Can I tape record this?
AN: Sure, as long as you don't use it against me
AMDS: I won't! [laughter]
Well, I'd like to ask you some questions about the Sydney
Opera House and that project
AN: Yeah, ok, good.
AMDS: I have some questions about the background, about
the original project and the tests that you did about the
original project and your collaboration with the architects.
And lastly some questions about other information. So
background: at what point did you in Arup Acoustics
become involved in the refurbishment.
AN: It started of 1998 where we did a feasibility study so
that's seven years ago now. And that was into just enlarging
the orchestra pit. What we were looking at there was
whether we could bring the orchestra pit forward into the
auditorium and the thing that was an obstacle for that was
a tie-beam that goes across and holds up the shells. So
that study included some colleagues from the structures
and we came up with the idea that yes, we could move that
tie-beam and redirect in some way that would then allow
us to bring the orchestra pit forward. So that was really the
very first study – was that possible? And round about that
time – or slightly later – Utzon was re-engaged by the Opera
House Trust.
AMDS: Ok, so that happened later?
AN: I'd have to check the time but round about 99 or 2000,
it might have been 2001, the dates are a bit vague. They
were then doing a thing called the Utzon Design Principles
and Strategic Building Plan for the whole of the Opera
House. So part of that project was to then look at the...one
of the projects within this strategic Building Plan was to
enlarge the orchestra pit and to improve the auditorium
acoustics. So some money was put aside. The firms were
ourselves and two American consultants. And in 2002 we
were interviewed and we tended - we put in a prize for the
work on the opera theatre and we were selected out of
three and that was 2002 and we signed the contract in
September 2002. And that's really where the work began
in earnest. On looking on the acoustics of the opera theatre
– again.
AMDS: Ok. And who from Arups has been working on it? I've
got here Rob Harris, yourself, Jason Cameron.
AN: Ok, let me take it a bit further. See in 2002 we did a
benchmark study which Jason might have mentioned to you
AMDS: yes
AN: that went on through to the early part of 2003. That
was probably a five, six month exercise and it highlighted
where things were good and where things were not so

good from an acoustics perspective. We were also then engaged in doing theatre consultancy advise and we had a sub-consultant working for us to help; Theatre Plan, who is theatre consultants.

AMDS: Ok, who is based in London

AN: Based in London. And in early 2003 we started a series of design studies saying “we now know what the issues are in the opera theatre what can we do?” so we started looking at the design of the building. And again it was a sort of very early feasibility study to do that and there were three or four options that came out of that and one of them was to stick with the existing theatre but just to refurbish it and to move the pit forward to deal with the acoustics. And after that – that took us to around about the middle of 2003 – we then presented that scheme to various people all the way through to August that year 2003 when we took it to Bob Carr. So it was a lot of discussion about the scheme and its potential benefits after that point. After that we were then appointed to do the concept design so we did a concept design for a few months, it took us up to around about Christmas time and that was really more about getting costs. It was about that much of a concept design (holding his fingers one centimetre apart to indicate very little).

AMDS: Ok

AN: To really understand the magnitude of cost. Beginning of 2004 we embarked on the concept design. Now, the concept period is round about an 18 month period. So our work from there – really it was February when we got started – took us through to February this year where we have done the first part of the concept design. So we’ve probably got between 6 and 8 months to run.

AMDS: Ok. And where... you have been working all along on this process with the architect as well

AN: Yes

AMDS: or where did you actually get involved. It seems like perhaps there were two legs of it (indicating two parallel legs of the process)

AN: No, no. For the majority of the early days it was really just us and the architect. In 2003 the theatre consultant joined in so really there were three key disciplines – in terms of design. There were teams of project managers and stuff like that in the background and teams of engineers but principally while we were working on the fundamentals of the auditorium it was those three teams. And the architect – Richard Johnson – have you met Richard Johnson?

AMDS: Yes, several times

AN: yes...with the Jorn Utzon team. And he was really working in collaboration with Jorn Utzon. (correcting himself) Is working. So ehm...yeah, I guess... we were working very much in parallel, crossing things over. So it was very much a small team developing that.

AMDS: Ok

AN: And ehm... perhaps a little bit different from how it was done originally

AMDS: Yes certainly

AN: So we were working pretty hard on getting what we could out of the opera theatre. So...

AMDS: ok..

AN: ...so you asked who was involved, didn’t you

AMDS: yeah.

AN: So it was myself, I’m the project director of Arups Acoustics, Rob Harris is working as our auditorium adviser, Jason was working as our manager – he was managing the team, then we’ve got – all up we’ve got about 12 people working on the project. Just from Arup acoustics

AMDS: that’s quite a group

AN: yes, it’s quite a team. So from here we had three people in Melbourne and we had three, maybe four, people in London, so quite a large team. We probably had 15 people working on it all together but the most at any time was 12 people.

AMDS: Ok.

AN: it is quite a big team – for what we do.

AMDS: how many are you in Arup acoustics all together?

AN: about 150

AMDS: ok.

AN: So it wasn’t everybody working on it, but it was quite a large team. [laughter]

AMDS: Then – I’ve of course visited Richard Johnson and seen the drawings and tried to get an idea about where the design was coming from and going and so on and of course one of the main thing that is inspiring it, is the Jorn Utzon original proposal. And the main idea of that proposal was that the whole ceiling should be reflective and that should actually be the main reflective surface onto the audience that should be the main absorbing surface.

AN: Yep

AMDS: That proposal was criticised a lot by the Danish acousticians...

AN: Jordan...yes.

AMDS: ...at that time. What was your initial view upon the proposal when you saw it? Did you think it was realistic and how finished – I mean of course there was work to do on it but how finished did you consider it to be?

AN: not at all. The ceiling shape has changed a lot since we started working on it and I don’t know that there were ever going to be just an insertion of Utzon’s ceiling onto the plan geometry. I think we always undertook to re-shape his ceiling within the radial geometry concept. But really we sought to refine that geometry to a point where it was working acoustically. And it is quite different to any other opera house ceiling in the world

AMDS: yes certainly

AN: It has these sort of flat ceiling and either flat walls or stepped out so you’ve got yourself a t-shape. This is completely different, it is going of like that (drawing an outline of the ceiling in the air). I suppose one of the things... when there is a really hard puzzle to solve they come to people like Arup to solve it because we do have an experience and a reputation for finding solutions to awkward puzzles. [laughter] that is a very flowery way of saying that we are pretty good at these things and that’s

why they come to us. The issues of the ceiling has really to do with the back... because we are constrained by the shell geometry and we have a ceiling where we are trying to get that sort of shape (rectangular) underneath that sort of geometry (the triangular space underneath the shell) and Utzon was trying to get his radial geometry increasing like this (follow the shell) go up in and as such is starts to come down and we end up doing something like that (steps down from the top ceiling to meet the vertical side walls). So it starts to come down and encroach on these upper side walls of the auditorium and the upper side walls of the auditorium are quite important for generation of reverberance and so we have several things which we are still resolving and we haven't finished this work yet but one way of resolving where the ceiling lands in cross section on the side wall geometry...the side wall geometry is a lot easier to solve...

AMDS: ...than the ceiling, yeah...

AN: and the other thing we have to resolve is when it comes down there it has got to get down at a certain height because of the shell and because we're dropping the auditorium down. And in doing that you actually end up with quite big steps and that's quite an unusual shape for a ceiling to have a stepped geometry like that – and what that does. So those are things were still resolving in our minds at least in our heads. We've gone a certain length along the line to think about how it's behaving [coffee coming in]

AN: So there is a bit to resolve still that makes it even more exiting this stage in the work.

AMDS: So you weren't totally put off by this idea about taking up Utzon's old idea?

AN: we were cautious, we were cautious and we - and Richard is aware of this – we said from the outset of that this was quite a challenge and not to underestimate what might need to be done and not to... to keep an open mind that it is not necessarily going to be this pure ceiling. And I think Utzon is quite open to the fact that there needs to be some sort of objects that is complimentary to his ceiling to compensate for what the shape of the ceiling might be doing. But certainly what we have learned the last twelve months of the concept design while we have been modelling what we have been doing gives us more confidence than we had twelve months ago. That the ceiling can be made to work.

AMDS: Alright

AN: That is a good sign

AMDS: Certainly! Ok. The original proposal didn't really have a lot of side reflection surfaces. It took all the sound to the back of the room.

AN: That's right, the fan geometry

AMDS: can you see something in that, that was perhaps also historically ... comes from a historical point of view... because before the acoustics was perhaps not as concerned with side reflections and binaural...what do you call it, the fact that you have got to get sound to both ears but more with reverberation time and some other parameters. Do you think that that might also be causing this kind of proposal Utzon came up with first?

AN: It is interesting because Utzon has radial geometry for the walls in his original proposal and that's still there in his mind but in the drawings – have you seen the drawings?

AMDS: yes

AN: what they are showing is actually a correction to that. It is going to be experienced as a radial geometry but the strategic point – we're actually correcting the fan to more of a rectilinear shape to redirect the sound back across the stalls and certainly in that upper cubic volume – the upper resonant volume – so that's actually quite workable and I guess one of the challenges we have is that the auditorium is naturally strained by the shells and circulation is needed on either side of it and the structure of the walls, so the more we interfere with the radial geometry the more space we lose at the risk that the auditorium just becomes too narrow. At the moment it is round about right, so that's lucky.

AMDS: it is just (showing balancing)

AN: yes, it is slightly on the edge and there's a risk that it becomes slightly disproportionate width to height ratio ...something we need to consider.

AMDS: ok, Jason was telling me about that you worked a lot with Odeon and tried to – I guess this is what you called the benchmarking test. Did you also test the original proposal?

AN: Now, ehm. The benchmarking was a geometrical and acoustical parameter study. So we did measurements in the existing theatre of reverberance, early decay, loudness, LEF – lateral energy fractions...ehm clarity, did I mention clarity?

AMDS: no not yet

AN: so a whole lot of acousticalbackground noise level. And we had data from other internationally recognised opera theatres. So that's what we did there with the benchmarking and it actually showed us where we scored positively and negatively against what is considered to be the great operahouses around the world. So that is how we used that benchmarking study. Where we use Odeon; Odeon is an advanced computer software program for modelling and predicting acoustical parameters based on a three dimensional geometry – architectural model. And we assigned surface characteristics, whether it is sound reflective or sound diffusive or sound absorbtive and we give it a whole lot of properties which we know we can use. And so we were able to - with Odeon – we were able to model the existing auditorium and we were able to then calibrate that model against what we had measured so that was quite important. So that was our sort of starting point. To know that the geometry and the assigning of the surface materials in the theatre were working properly and when we started to do modifications we were able to put those into the Odeon model to examine what the changes were to those acoustical parameters.

AMDS: ok

AN: So one of the measures that we were keen to improve was the reverberation time

AMDS: yes, its very low

AN: it's low, it's a very dry auditorium. So to give the music some warmth and give the voice a bit more resonance. So we were trying to do that, Arup tried to do that. Odeon allowed us to predict what it might be based on geometrical changes. The architect and the structural engineers were working with a package called TriForma

AMDS: Yes, I have seen the results of it, I don't know the actual program

AN: It's a microstation based program. But it does things in three dimensions and we were just putting that into our acoustic model.

AMDS: I have been working with CATT which is almost the same

AN: yeah... so you have been using Cad or Catt?

AMDS: C-A-T-T

AN: Alright, where were you doing that?

AMDS: At Aalborg University, in Denmark

AN: because that's where it was developed wasn't it?

AMDS: no, it was developed in Sweden. Odeon was developed in Denmark, in Lyngby, at the technical university in Copenhagen and my university I don't think they have developed any acoustical program but they use CATT.

AN: We use both CATT and Odeon.

AMDS: How come?

AN: Eh... We just... for this Odeon is more appropriate, we have also done lots of other auditoria and opera theatres in Odeon and it allows us to – in a completed auditoria – to go back and check our measurements against the model so we can see how accurate the modelling technique is.

It allows us then to post-change percentage differences so if for example we know that Odeon overpredicts the reverberance; different versions of Odeon overpredict reverberance.

AMDS: Ok, so you are able to take of the right percentage

AN: so we know... the reason why we know this is that we do the model and when we go and measure it, it is dryer than we expected. We can understand that or we can compensate that. So Catt, we have been using catt before Odeon on lots of spaces, we've done a number of auditoria in catt, school spaces. Some people like Catt, some people like Odeon. Odeon is a bit more sophisticated in some ways.

AMDS: yeah. Al right, a bit more about the collaboration with the architect. Also connecting back to Odeon because how do you see this program as being able to communicate with other professions?

AN: Well there is a next step from Odeon which I might talk about and that might answer your question slightly better which is that the next thing we want to do is to do a scale model of the auditoria, an acoustic scale model. Probably a 1 to 50 model initially. Are you familiar with scale modelling?

AMDS: Yes, I thought it wasn't used a lot actually.

AN: No, we use it quite a lot. We pioneered it in the 80'ties as a practice. Mike Barron and a guy called Raf Orlowski who...he works within Arup Acoustics, Raf does. They really sort of pioneered it as a method of testing and designing.

AMDS: Ok.

AN: So our intention will be to, in the next stage, to do a scale model for two reasons. First of all it allows us to get another degree of accuracy on the things we are doing on the issues of ceiling shapes and what have we and we can start to get another set of results which we can set on the side of Odeon and say 'Odeon is saying this and the scale model is saying that and our instinct is saying this' and so ehm... that is sort of the next step. It also then allows the architect to see if the design is evolving and as we play with the model because we will adjust things and we'll change geometry and we'll change materials and stuff like that and we'll see what the effect is. It allows them to see that too. It allows the client to see that – he can see what it's like in the auditorium. Today we've been working on half polystyrene models – did Jason show you any of those?

AMDS: No but I think it is the same as I've seen in...ehm

AN: JPW of course. So we were using those and we put reflective tape on it, we used a laser and we looked to see where the sound bounces to. Very crude but very useful to get an early picture of what the geometry was doing. So that's the next step we want to get to, to get a model to put alongside the Odeon model. That'll then allow us to test the results a bit more rigorously and then after that as the design is developing we'll get to a point where 90% of the concept is locked in. We're thinking about doing either a 1:10 or a 1:20 scale model. It is a huge thing.

AMDS: Yeah it's going to be fascinating

AN: So that is going to be quite an interesting exercise and that'll allow us to see the auditorium by building such a large model. At the same time you ask about collaboration. Of course doing such a project of that size is incredible collaborative because if there are any changes we are trying to do geometrically for an acoustic reason will have a big impact on what the architect is willing to accept or might consider. So we have to get their endorsement on anything and we do get their endorsement on anything. And I, I found the process very collaborative for two reasons, one is that we have Richard Johnson who is a very clever and collaborative architect – he's actually good fun to work with – and he has the highest respect for and from Utzon and they do behave like one. You can second guess what Utzon is going to say through Richard and that to me is very good. So there is a comfortable body there which works very well. So the collaboration has been terrific, very interesting. I hope Richard tells a similar thing.

AMDS: He did, certainly! [laughter]

AN: Yeah, he is a delight to work with. And Utzon, we met with Jan...

AMDS: did you not also meet with Jorn?

AN: I haven't met Jorn, not yet. We've talked about it but we had a workshop in Copenhagen...

AMDS: ...yes, that was what I was thinking of.

AN: ... Jan was there but Jorn wasn't. Only because of illness, I think. I may be wrong about that, don't quote me on that. I had to leave early also...Richard met him.

AMDS: Yes, he mentioned also about illness in the family, so...

400 AN: we had a number of international workshops either here or in Europe but they are generally architect, acoustician, theatre consultant and the project manager comes too.
 AMDS: ok, and how long would they be those workshops?
 405 AN: usually a week. Maybe a weekend and a couple of days. They are long enough, you run out of ideas and you run out of what you can do without actually having your own time to do things.
 AMDS: yeah. Ok. So how do you see your own role in the project, being an acoustical consultant. Do you see yourself
 410 as one to educate the architect about acoustics, solving problems that comes from the architectural design, to sit down and understand the design intentions and then actually get to design yourself or how do understand yourself?
 415 AN: The way I describe what an acoustician does is that we are actually very lucky because acoustics has an involvement in all aspects in the building – in the services, the structure, the fire engineering, the electrical. Everything
 420 that going into this building we have to have an interest in it whether it is because of the geometry or whether it is because of stopping noise in some way and all of these things are critical to us. So as an acoustical consultant we are working with everybody and when we are talking
 425 about geometrical things it really has to do with what Richard is doing - and the theatre consultants of course. So we are very lucky, really, because we get to know everything that goes on in the building. The downside of that is that you need large teams to be across the whole
 430 thing. The other way I look at it, is that acoustics is not another layer that goes on either underneath or above the architecture, acoustics is very much a part of the architecture. So, you know, this door for example, this door is providing in two roles – as an architectural thing,
 435 its visuals and stopping people coming in, it's acoustical, it is performing an acoustical role – not very well because there are wholes in it – but it has an acoustical function. And so...ehm...but there is no extra layer. There isn't a door there for architectural reasons and there isn't a door there
 440 for acoustics, there is one – and that is really harmonious design. So you know when we came to design this room the architect and the acoustician collaborated 'so we want a door acoustically and you want a door architecturally – let's make it the same door'. A very simplistic justification
 445 of what we do and you'd understand this as an architect having studied acoustics but if you apply that to this project you can actually see how that philosophy needs to work, which is that everything which Utzon and Johnson draw they will need to get our agreement to it because it has an
 450 impact. If you change the geometry of a surface area or something we have a strong interest in it. You might think you are only doing it for architectural reasons because you've got to move such and such to get a beam through or to get services through but that is not the case at all.
 455 AMDS: Ok so you are actually saying that it is all of them – that you need to understand the design intent ...

AN: yes
 AMDS: ...and the architect need to understand the acoustician.
 AN: But the architect has to understand everybody too. 460
 Another example is that if we are designing a room like this and if the services engineer wants to stick a piece of ductwork from one side to the other, they'll say we'll put it from there to there (pointing a straight line) to get the shortest route. The architect will say 'well I don't want it to go there, I want it to go here, which is nearly the shortest route but the reason for that is that I don't want to see it there'. We'll have a say in it because we'll say 'hold on guys, we want this thing to be twice the size because as it is it is too noise, it'll never be quiet enough for this room. 465
 Therefore we want it to round and...' whatever. Those are sorts of examples, again using a very simplistic, you know duct-to-the-ceiling type of example. That is...if you apply that to the opera house, that is what we are doing.
 AMDS: Do you think this is normally quite easy or quite difficult? 475
 AN: It is complex.
 AMDS: Yeah. And how would the architects normally understand that role or that communication?
 AN: They do. I mean Richard and Utzon, particularly Richard 480 because we spend more time with him. Richard is very understanding of our key acoustical requirements and he can speak quite animatedly about acoustics, having spend the last three years working so closely with us. It is an intuitive thing, he understands what it is that we need to do and what he needs to do. So that works quite well. [So you know we the phase where we're drawing something for architectural sake and not consulting with what we do] ... we all still learn.
 AMDS: Yes.... We should [laughter]. And do you think that is generally the case among architects or is it just because this project has turned out as it has or? 490
 AN: Some are good, some are not so good.
 AMDS: Yeah, ok.
 AN: And I try not to use, you've mentioned the word 'educate', that sounds a little bit...to me it sound a little bit school-master'ish, you know 'you must do this, or...' Cause they might say 'Well, I've done it because of this' – they are going to have their reasons for not it or doing it. So I guess the way around that is to talk about or persuade the architect about the importance, let them listen and understand the things that make a difference. We have a laboratory up in Melbourne, down in Melbourne, which does all that, which allows us to listen in a very controlled environment to auralisation, which you are probably familiar with. In this case it is a room which has got 12 loudspeakers pointing at you in the middle. We can play before and after scenarios and listen to the difference. So we can get people to make decisions based on that opposed to numbers – numerical decisions. That is very powerful. So next time you are in Melbourne – this'll be our next meeting. 500
 AMDS: that would be really good. And that is quite new isn't 510

it?

515 AN: Yes, that been opened in... the last three or four months. We've been putting it in the press quite a lot just to getting used to having it. So do you plan to come to Melbourne at all?
AMDS: yes I do.

520 AN: have you ever been there before?
AMDS: no, never. I hear it is lovely.
AN: Well let me know when you are coming.
AMDS: Yes, I will. Ok, one last question before going to the last part. Do you think you work together in a different manner due to Utzon's influence. Of course Richard thinks so but do you think so?

525 AN: yes I do, I think we work in a really interesting way with Utzon. Perhaps in a normal design of an Opera Theatre there is a lot of more Things move quickly, decisions are made on a weekly basis. For example the Copenhagen Opera House, the Henning Larsen building, my colleagues were there every week for several days of the week. The design was intensive and on-going because of things being built while it was designed. Decisions had to be made. And

530 so that happened all the way through. With this wonderful building we have bursts of design energy while we are all together and we have these international workshops and then we have periods where we meet up on fort nightly basis, we have video conferences where we report back to the group. We do that and then we have international video conferences every two to three weeks and then we come back together again so the time between discussing a decision and to when it gets implemented or shown in the drawings could be anything up to a month. Whereas

535 in Copenhagen it was the next day and the next problem would come up. So we work in a different tempo here and it's still full of stress and issues like completion but it has been really enjoyable.
AMDS: Ok.

540 AN: It wouldn't necessarily apply to normal projects.
AMDS: No, I could imagine. Also because there is actually no funding at the moment.
AN: No.
AMDS: Well of course you are expecting it or hoping to get it

545 [laughing at an crossing his fingers]
AN: We keep our fingers crossed. There has been a lot of talk in the papers in the last few days as you'll have seen and something will happen - one way or the other.
AMDS: Yeah. Richard Johnson was giving a talk at the

550 Opera... no at the Museum of Sydney the other day and somebody was asking about the funding of course and he was just 'we'll see, we'll see, don't worry about that now'. [laughter]. The last thing is documents. I am trying to track quite detailed the process that you've been going through which is of course a bit difficult because it has already passed. And that is why I am looking for interim reports, minutes of meetings and so on. And asking for them because it is probably not even a thing that you are interested in giving out of course.

555 AN: I don't know that I am allowed to, I am afraid. Did you meet the project manager?
AMDS: No.
AN: Did Richard give you anything?
AMDS: Not yet.
AN: I don't know whether we are allowed to. We had to sign confidentiality agreement so we don't actually own this stuff and a lot of it is not in the public domain yet, so if I was to give it to you I'd probably get my knuckles rapped – so much as I'd love to give it to you.

560 AMDS: Ok.
AN: Minutes of meetings; I'm sure the same thing would apply to that. It is not one that I can answer. You can ask the Opera House.
AMDS: Ok, are they the ones that I should be asking? So you'd say Gillespie or?

565 AN: Gillespie would tell you, he's the CEO, whether you'd get an answer I don't know. Have you spoken to him yet?
AMDS: No I haven't but I have him on my list to contact. I spoke to Joseph Skrynski.
AN: Yeah, and what did he say?

570 AMDS: Oh he said 'arh, they'll give it to you, don't worry'.
AN: [laughter] Ah, good old Joe. The problem they have at the moment is that, as you have seen in the papers, there is a number of negative reactions or comments in the press 'it is never gonna happen' and so on. People are getting a little bit anxious and the opera house is quite cautious so I would be very reluctant in what I am allowed to give out at the moment so... as much as I'd want to give it to you.

575 AMDS: I can understand that.
AN: But as I keep reminding my colleagues, Arups has actually been involved longer than anybody else in this project – even longer than Utzon. So we're actually one of the partners having the longest relationship with the building so why shouldn't we be the ones making those decisions. But it is not quite that easy – but I like to say that. I am being provocative for the tape [laughter]. We can meet again, how long are you here in Australia for?

580 AMDS: I am here another three months so I would really like to meet again.
AN: ok, was there anything else you wanted to ask me today
AMDS: no, I have taken your time
AN: (looking at watch) bang on. So tell me when you want to get back together again
AMDS: yeah, that'll be good. Ehm... perhaps it would be best if I came to Melbourne next time?

585 AN: That would be good
AMDS: So in a few weeks?
AN: Yeah, give me a few weeks I have quite a few trip over the next few weeks. Why don't you email me a couple of dates and you'll be down for a few days, won't you.

590 AMDS: Yeah, I will.

595

600

605

610

615

620

| | | |
|----|--|-----|
| | Interviewee: Andrew Nicol, Director Arup Acoustics Australasia [B] | |
| | Interviewer: Anne Marie Due Schmidt | |
| | Date: April 26 2005 | |
| 5 | Location: Meeting room in Arup Acoustic, Melbourne Office | |
| | Notes: Immediately before the interview, the interviewer was introduced to the Sound Lab (a small room where one is subjected to sound derived from | |
| 10 | acoustic computer simulation programs. The sound is transmitted from a number of loudspeakers placed in a spatial configuration and thereby gives the listener the same audio experience as one would have in the space simulated. At times the sound impression is | |
| 15 | supplemented with a projection of the view (e.g. a view towards the scene from a particular seat) one would see when having this audio experience). This Sound Lab is referred to in the interview. | |
| 20 | AMDS: Ok, I have a few questions. The last time you gave me a really good overview and like the whole structure of what happened when and today I'd like to ask a bit more about the process in the acoustics in the design project | |
| 25 | that you did - starting with the sketch from Jan Utzon in January 2004. You described the objectives of the brief, the benchmarking, the over-all design options, so with regards to the beginning of the concept design I'd like to ask you: how did you work with the acoustics and which tools did you | |
| 30 | use? Because the last time we talked about a few of them like the simulation programs and the very rough models that you had... | |
| | AN: Yes, yes. | |
| 35 | AMDS: ...and you were talking about the laser and the reflective tape. But could you give me an idea about which tools you used and in which order you used them. | |
| | AN: I'll try and remember. Are you recording this? | |
| | AMDS: Yes I am recording this. Is that alright? | |
| 40 | AN: Yes, that is fine. So let me think what happened. The first thing we had to do was that we had to set some design rules for Jan and Jorn and Richard Johnson, who was working with the two. And they're basically what we call the acoustic design rules. So they cover things from the overall volume of the auditorium to the volume | |
| 45 | per seat, the volume per seated area which is slightly different – that includes areas at the pit and areas at the proscenium – geometrical targets in terms of dimensions of the orchestra pit, dimensions of the width of the theatre, ideal dimensions for the height of the ceiling – although | |
| 50 | this auditorium is different, which I think we talked about last time. And other dimensions – rake of the auditorium seating area, distance from the stalls front... sorry from the stage front to the front balcony. All of these were rules which we wanted...you know, they weren't absolute but they | |
| 55 | were in a range. Some of them were absolute but most of them were 'they need to be within this range'. So this was the sort of the design guide that we sent to the Utzons. | |
| | Along with that we had some design notes for him, which described the types of materials that would be suitable acoustically in whatever location so that would describe the | 60 |
| | seating, the floor construction, the wall construction, the types of finish whether it's absorptive, diffusive, diffractive. The weight for the ceiling. So we went through... these were really some rules. And then they'd come back with their | |
| | sketches. | 65 |
| | AMDS: But doesn't these things depend on each other or ... | |
| | AN: They are interrelated, yes, but there are things that we would know for a 1650 seat opera theatre: 'these are the generic properties that we are looking for'. There is some tolerance because if you move one thing another thing will | 70 |
| | have to change to reflect that. We...ehm...we wanted to give them a starting point if nothing else. So then they would come back with a set of sketches which was their drawings and that would be drawn in tri-forma – the Microstation | |
| | drawing package – and what we then did...each time we then got...the way we worked was that they would then freeze a set of drawings and this would become sort of | 75 |
| | 'Day Zero' of 'Scheme whatever' and while there were lots of iterations architecturally for that scheme they were continuing to consider, the way we worked were that we | 80 |
| | would freeze the scheme and we'd work on it from an acoustic perspective and other people would look at theatre and other issues.... | |
| | AMDS: ok, so start understanding the acoustics... | |
| | AN: and we'd test it to a point where we would either say | 85 |
| | 'yes, this is going well' or 'no, we can't pursue this'. And so then we'd present back the findings from that. Now, the way we tested that was that we did some manipulation of the drawing from Microstation, or TriForma, putting it in to | |
| | Odeon - we had to do some translation to represent the curvature of the ceiling because, as you know, they don't see it as a curve and Odeon doesn't read it as a curve so | 90 |
| | we had to put it up in two series of cuttings. Then we'd convert it into an Odeon model that would allow us to look at the model and asses it's acoustical quality. So that was the principal tool that we were using through the concept | 95 |
| | design process. So each one [concept] would have an Odeon model tested for it. And then we would look at the output in the model, we would look at reverberant, we would look at...we'd obviously... before we'd be doing the | 100 |
| | model we would be checking fundamental parameters again, what we said we wanted, so the design guide we would go through and actually see whether or not we had achieved it. So that can provide some feedback. And then the Odeon model would assess the acoustical behaviour | 105 |
| | of that scheme's iteration and that would be fed back to the design team through Richard to Jan and Jorn and so that would start to generate the next iteration. We would also make some visual comments from the drawings, for | |
| | example when we looked at the drawing of the auditorium there were certain surfaces that we knew were not aligned | 110 |
| | in the right direction, just in plan, because of his radial geometry. We knew that there were certain surfaces which were sending too much sound to the back. [All they were | |

- 115 certain surfaces that couldn't be seen by sound on the stage nor from the pit] So we would get Jorn or Jan through Richard to make an alteration to the plan and after about four or five months we had the plan shape pretty well locked away. Another course which were related to what
- 120 was going on was related to circulation and we got to a point where the boundary was set independently from what was going on in the circulation so we knew we could move those shapes around a little bit within the depth of the structure and that allowed us to work out the right shape.
- 125 And then as before, if something changed we'd...you know that might effect something over here, so we had to keep looking for all those kinds of things. So that's how we went through progressively evaluating each scheme.
- AMDS: And how many schemes would you say that there were that had this treatment?
- 130 AN: I think we did nine or ten in the concept period – so far.
- AMDS: So far, yes of course.
- AN: I think it was that number. Whether we did that to the same degree... some we did more and some we did less.
- 135 But I've got something in my mind saying that we went up to revision ten.
- AMDS: Okay. And some of them were...were they actual schemes or were they also some investigations into something that you knew that wouldn't continue? Just to try
- 140 that out?
- AN: Yes, there were some. Look, as well as evaluating Jorn's scheme we were trying things in the model which would inform our advise to them on what to try next and we would try things like raising the ceiling or lowering the
- 145 ceiling or changing shape to the ceiling. To look at what was happening to the acoustical parameters because Odeon, which you know quite well, does give you a lot of output in terms of what you can look at.
- AMDS: Yeah.
- 150 AN: So it was an awful lot we could tell just doing that Odeon model.
- AMDS: Yeah. So when would you say that the first time you started building an Odeon model was? Was that with the first scheme even – with the January scheme, or?
- 155 AN: Well, the first model we did was a CATT model using CATT-acoustics. And we probably did that... in....March 2003 – this was when we were evaluating the three options for the Opera Theatre – one was to leave it as it is... Richard Johnson has probably explained these to you.
- 160 AMDS: No, I know there were three or four options, but not exactly what they were.
- AN: There were three main options, one was to keep the auditorium as it was and just make it as good we could by refining geometry and the seat number would be around
- 165 1150-1200 seats. That was option one. Option two was to drop down the stage with two and a half metres and that was what was called the stage to pit level so it was the stage dropped to the same level as the stage is at now. Then everything else drops. And the third option
- 170 was to drop the stage level right down to the green level which is four and a half metres, which is the option we have pursued in the concept. Now each of these options we evaluated in CATT before we did anything just to see what the possibilities were and we did things like taking the existing – well the new - room and sticking the original
- 175 Utzon ceiling on to it and just looking at it – just to see what it did. Similarly we did much more traditional opera house ceilings, just a flat ceiling, just to see what the levels were then. So we were able to do all these sorts of manipulations in the CATT-model. That then led us to the recommendation – along with a lot of other recommendations – that the main scheme is to drop the whole theatre by four and a half metres. So that is the one that started to be designed in January last year.
- AMDS: Ok.
- 185 AN: So we had done those previous models and we've got those in CATT. Then we decided to switch to Odeon because the scheme was too complex at the time and there was a lot of experience in opera house – opera theatre design using Odeon in our practice. We had Copenhagen Opera House just finishing which we were able to look at the design of...sorry; the output of Odeon and the measurements of the finished auditorium so we were able to compare all the parameters with the real thing and that allowed us to see how accurately Odeon was predicting
- 190 against what we've got in the completed building. And we were doing that with the guys that has developed Odeon and they kept changing Odeon to update to reflect that and each time they did that we then had to re-run the models to see how accurately Odeon was predicting with the changes
- 195 that they had made in the program.
- AMDS: Ok
- AN: So we actually started helping them to develop the program so we were probably using Odeon far more sophisticatedly than anybody in the world and possibly even
- 200 than...
- AMDS: ... the developers
- AN: ... the developers themselves! So our first Odeon model was round about May last year, maybe April. We started in January and we did three months of study, we stopped for
- 210 a while and then we started again. It was probably round about May-time.
- AMDS: And before you started using Odeon then, what kind of tools did you use then. I mean you had the geometrical shape
- 215 AN: Primarily it was geometrical, I mean the scheme was not well enough developed to use anything more analytical than that. So we had to really manipulate the design to a point where we were not just wasting our time modelling something which – you know – we knew wasn't going to work. That is the point we had to get to.
- 220 AMDS: ok. And...yeah...for instance this reflective tape that you were talking about, that was really amusing to me – I had never seen that before.
- AN: Yeah? Did I show you a model in the office?
- 225 AMDS: No but I have seen them at JPW's...
- AN: Right
- AMDS: So I know which ones you were talking about. At

230 what point would you use those ones? Would that be at the same time as Odeon or would it be before?
 AN: Earlier than Odeon
 AMDS: Yeah?
 AN: Well we used them on a number of the schemes but we would use them before the Odeon models were made
 235 because JPW worked at how to do this really early on and they could produce one of these models in a couple of days it was a lot quicker than getting the Odeon model done and it gave us quite a lot of information for us to study and to learn from it so we were probably doing those in March and
 240 April.
 The problem was – they were polystyrene models so sticking the tape on to them was quite tricky
 AMDS: Yeah I could imagine. Just a slight difference in tape will actually make a big difference.
 245 AN: Yeah, a huge difference. It was crude but it was just an indication.
 AMDS: Ok. So that's the Odeon and the geometrical shapes and as well as this funny thing with the reflective tape, what else would you use in the first period – or would you use
 250 anything else?
 AN: Ok, what we haven't done yet...because this is quite complex, it is very complex, what we would like to do - I think we are at a point where we could start to do this – is to build a scale model to test a scale model of the
 255 auditorium. If it was geometrically a more straight forward auditorium, we would have done this earlier on because the changes, the geometrical changes to the auditorium, could have been dealt with in the model. Whereas when we are talking about a ceiling shape like that, fundamental
 260 changes in that had a completely radical change to the whole of the geometry of the auditorium and we could not afford to keep changing. So I would have thought that – once the project restarts again – we'll be doing a testing of a scale model like that in either 1:20 or 1:50 scale. And
 265 that'll give us more certainty in what we are doing.
 Other analytical testing we would do...there is something more generic or building engineering stuff that we would do. And one of the things we had to do was measuring the sound transmission from outside to inside so we were
 270 measuring and that was quite a unique problem so we hung a loudspeaker up outside – did I tell you about this? – so we hung a loudspeaker up outside
 AMDS: Yes on a Sunday
 AN: Yep, and measuring simultaneous across the shells
 275 of the auditorium and that gave us a determination on how heavy the inner skin of the auditorium needed to be because we knew we couldn't do anything to the shells, so everything else had to be done - in terms of stopping sound coming in and sound coming out – everything had
 280 to be done in the airgap between the outer layer and the inner construction. The depth of that gap and how heavy this was and the position we got to when we were designing the concept was that this actually became a boxbeam construction, so very similar to what Utzon had in mind
 285 originally

AMDS: yes, very similar
 AN: And assume that the overlapping boxes would be like that, another box like that [indicating two boxes between each other, one box positioned higher than the other] would match the – and that would provide the sound insulation
 290 control. And then there was the layer of the roof above
 AMDS: the shell
 AN: so we used various acoustic prediction methodologies just using sketching technology to do all that, that was quite complex.
 295 AMDS: Yeah.
 AN: Ehm...what else would we use? Primarily it has all been done through Odeon.
 AMDS: Yeah, ok. Ehm...you said that you had these geometrical.. or like 'starting point' for the architects with
 300 the geometry of what it should do or what they should accomplish or try to accomplish
 AN: try to accomplish
 AMDS: yeah. How do you do that? Is that in the form of a small booklet or how does it come?
 305 AN: It was just a report type document quite straight forward. It was just a table we filled in progressively so we could look back at all the schemes. So each time we did a new iteration we labelled it and we saw what had been achieved and that sort of sat between two things: first of all
 310 Utzon and JPW were developing their own series of designs so for each scheme they would have basically a whole set of drawings, a whole set of images and a model. So that would sit there as a progressive story. We had this thing in the middle which was the rules that we were setting and
 315 the Utzon design principles was tapped there as well. And then we had a set of Odeon models so for each scheme we had our own model and our own output and that became another document which we sort of reported on at the end. We could see where the progressive increments or the
 320 backsteps were happening. So you know, these things were running in parallel bridged by what we were doing in the middle. At the same time the theatre consultants was doing sight line analysis, seating number analysis for each of the
 325 schemes. So there was another parallel stream where all of that was going on.
 AMDS: Okay, so they were taking care of that.
 AN: Yeah.
 AMDS: Ok, I thought actually that they were mainly back-stage.
 330 AN: No, no. The theatre consultant, who is a theatre architect, advising JPW and Utzon on how to design the theatre side of the auditorium which is slightly different from what it looks like; it is actually how the form with the seating works out
 335 AMDS: and circulation?
 AN: and circulation. The relationship between people, the sightlines whether the rake does that [go flat] or should it do this [form a curve with the lowest point in the middle of the auditorium], changing the shape as it goes around.
 340 AMDS: Ok, I see
 AN: It is quite complicated all of that.

AMDS: Ok.... So it was mainly a table that you had filled in with all these requirements that you wanted. But what
345 about like rules of thumb from acousticians... of course there are some of that in volume but for instance what kind of shapes for the side walls, would that be a part of that or was that more something that you commented on when they...

350 AN: Rules of thumb, the whole document was a rule of thumb which was an Arup Acoustics guide to how to design an opera house and so that comes from historical experience that we've got as a practice and it was intended to guide Utzon and Richard Johnson in a direction, it wasn't
355 to shoehorn them into something that wasn't geometrically a workable shape. And so, but what we found, and what was quite important, was that in terms of plan-shape and in fact any geometrical shape, after a while of working together, the Utzons, JPW and ourselves, they would know
360 what it was that we wanted acoustically. So they would even come to us with some schemes saying 'we know this is not going to work because you'll tell us dadada, but we just want to see where it goes.' And all that is quite interesting because it might necessarily give you the sort of response
365 to the rules that we set but it might set you off in a way – as you said before, if you change one thing, it changes something else here and so the whole thing might actually work for a different reason or there might be a different form of compromise or something along the way. So...it's
370 not absolutes. There is a lot of science behind it... the Odeon modelling... but the rules of thumb they are not just made up.
AMDS: No, no.
AN: They are things we know that are needed to get things
375 to work.
AMDS: yeah.
AN: They have some flexibility. This is not a repeatable auditorium.
AMDS: not at all. Which I guess many of them are
380 AN: yeah.
AMDS: No, I was just asking because, when you do something like this would it be almost like, yeah as you say, Arup guide to how to do an auditorium because what about... as one of the problems Utzon had in the first design
385 project where he didn't know that a convex...a concave shape would create problems acoustically. Would that be included in such a thing or would that more be something that you would comment on...
AN: It's in the design notes that we issued in terms of what
390 materials and shape of materials is good acoustically, so we have issued some design guide lines and that sort of thing would be covered there. But again there is...if Utzon said 'this absolutely has to be material x' it could be that, while it is not what you'd normally have, we can compensate for
395 it by something else. There is some room to manoeuvre – to a point. And they would start to understand that. In the discussions about those sorts of thing...or: there are discussions about those sorts of things but they are not necessarily, you know, [tapping his finger in the table as
a school master] 'you absolutely can not do this'. We are more saying 'ok, we consider that but there may be this, this and this to compensate for that'. And Utzon would then consider whether or not he was particular wedded to this concept because of what it did elsewhere. So all of that sort of discussion has been happening. And they are pretty
405 well aware of it, I think. It's intuition; it's sort of...that sort of relationship between architect and acoustician, the bond, when each knows what the other is going to do, sort of predicts the next move, that is what has happening now. It takes a while to get to that point.
AMDS: Certainly. Also, you are new people to each other. It takes a while just to get to know each other.
AN: Yes, and doing it through the JPW, Jan and that route there makes it even more complex, which is why we only went through a certain number of iterations in the twelve
415 months because Jan needs time...Jorn needs time to consider. We need time to consider what he is saying so the whole thing is quite ponderous, it'll be worth it though.
AMDS: Yeah, hope it'll be build
AN: It must
420 AMDS: Ehm... the last time we were also talking about your reactions to the original idea and that Arup was very cautious about the project. could you walk me through again, I mean somehow it is the same question, but I would like to hear it from you, what your thoughts were when you saw the original idea.
425 AN: Let me show you, I remember this quite well. [standing up and walking to the white board and starts drawing a section of the original proposal while he is talking] In the original idea we had the proscenium here, the space coming out here, the flytower. And the original ceiling did something like [drawing]... uh... [erasing and drawing again], the stalls something like this and the balcony and the next balcony...something like that. And...this is probably not drawn to scale...not to worry. And immediately we
430 could spot a number of things that were problematic...this is our sound source here and we have surfaces up here [front part of ceiling curves] which return sound reflections straight down to here [front part of stalls or onto the stage] – that was a problem in terms of the original geometry. Now we were able to show this in a sectional way in this way [as shown on the white board]. Although it is a centre line – it does not consider the radialness of the geometry, it does not consider lots of aspects of the scheme, we knew that this would be a problem. And there are other things like
445 this – there was an element of this, that was going to do something like that and bounce back into the flytower [the part of the ceiling over the stage bounces the reflections back and forward and sends them back to the flytower]. So we could already just by some simple ray-tracing we could see... perhaps one of the earlier schemes had this leaning further forward [the part of the ceiling over the stage] and we knew that was going to be a problem... also we were loosing all of this volume here so this is why this came about and in doing that – to get that volume – we started
450 to get these funny reflections. So the whole was totally

interrelated – if we did that we were considering hanging some objects from the ceiling [to close of the highest part of the ceiling and not get the long reflections but keeping the volume] – we considered a whole lot of things. All these things were considered by the architect and the ourselves but that is quite fundamental. Two things – one is the encapsulated volume which is this stuff here [drawing an outline around the whole auditorium] that had to be a certain 11500m³. But it wasn't only the case to within that [line] to get that volume because what we needed to get the reverberance the 1.4s, we knew that we needed to get the reverberance building in here [the upper volume, not over the stalls or over the balconies] so the reverberance doesn't build in here [over the balconies] because there is too much of an overhang so if don't have sufficient volume in here then - frankly we weren't winning. And because of the geometry of the ceiling and what we found from the ray-tracing we were loosing this volume [over the stage] so we had to push it up and as we pushed it up, it became flatter [inaudible sentence] ...we did a lot of things

AMDS: and that is still going on

AN: that is still going on, we haven't resolved that yet. So that is the sort of stuff we have to do and it is very much about design, it is not all about the computers. It is actually about thinking about sound and how it is flying around the room and those are sorts of things you can just do with pieces of paper and time and thinking....but remembering that it's not only about first order reflections. You have studied acoustics so you know what I mean [goes to the board and draws it], but we had to think about what happens to the sound that does something like this, which comes of the wall, then come down like this – that's first order, that's second order, that's third order reflections. So that is where Odeon's strength comes in, while you can do certain bits of that using ray-tracing as I am doing, Odeon does it in the computer, so you can follow those traces for much longer and you can do a lot more of them so that's when Odeon comes into strength when we had something that was worth examining in that much of detail.

AMDS: And when it is so complex and three dimensional, it must be almost impossible to do by hand?

AN: We couldn't have done this in two dimensions – at all. And eventually we use this place here, the soundlab.

AMDS: Isn't it normally very difficult for the clients to hear – and also to make up their mind?

AN: Yeah, you had a very short demonstration. In order to make really sensible design decisions you have to go through very carefully step-by-step and actually learning people to listen properly because it is very hard to listen.

AMDS: Also the exercise with the box was really good just to get an idea about how important that is.

AN: Yeah.

AMDS: Ehm...there was this last thing, that we have been over, the fan-shape of the auditorium must have been one of the things that you were concerned about.

AN: Yep, for the same reason...the radial geometry was essentially like that [drawing Utzon's fan on the white-

board] so what we essentially tried to do, we tried to correct the fan by having it shaped like that [less radial, so the walls can be reflecting the sound] these early reflections here were important to get the reflections across to the stalls. Then when you start to get these sorts of things [some of the reflections from the wall is caught by the 'outhead' of the wall] in the fan plan that does not do anything at all because they are shadowed by the geometry itself. So the stepping back in itself is why the fan is not good – you would actually try to step it forward. When you step it forward you start to loose seating area. Essentially what you really want to do is that [even out the wall] and then you don't have the issues of shadowing and the unuseful reflections. So what we have been trying to do is a compromise between the two and that is what we have been drawing. They have become quite good. We quite like it, that is quite resolved. It is not that pronounced, it is not that bad [referring to the drawing]. I am just using a little bit of artistic license on the wall there.

AMDS: Fine, it explains it very well. Ok, you said before that you tried to just build the model in 2003 with the Utzon-ceiling, what did you learn from that? Was that what you were drawing before?

AN: It was really more about learning about the auditorium and how the things might behave but at that stage it was so early in the design that it wasn't a serious thing. It was literally 'if we dropped the floor down and stuck the ceiling on top, what sort of volume would we get and would it be anywhere near our target?' So it was really that crude. It wouldn't draw anything from it and I wouldn't want anything repeated about that it was a way of technically evaluating it,

AMDS: no, okay, it was more about the volume

AN: it was a crude sort of 'is it worth it?' But what we did do, was that we did try to recreate the existing auditorium with the Utzon-ceiling on the top and see what difference it would make – and it was still a very dry auditorium, not surprisingly cause the shape of the ceiling sends all the sound down to the seats and the rest of the geometry is sending all the sound to the seats, so there was no life in the auditorium at the moment. The new ceiling would not – on its own – have made a difference. So the new ceiling with some other differences might make a difference.

AMDS: And then afterwards, did you not also try the exercise the other way around by trying to put a flat ceiling on top of the new room, what did that show you?

AN: There was a loss of volume because of the shape. Essentially what was happening was that if we did that [draws a cross-section and shows how the ceiling goes up in the tip of the shell and the flat ceiling doesn't] so we would loose all of this volume here, it wasn't big enough for that, so we lost too much – 2000m³ I think. Not just there but from all over the thing, so it was getting to pressed.

AMDS: So would it be fair to say that it was quite a good shape for this space under the shells?

AN: No, I wouldn't say that necessarily. Architecturally yes it was but acoustically I don't think... look it's a really hard solution and we haven't yet gotten to the bottom of

it. Maybe this is one of the better solutions but I wouldn't say 'yes, this is what we'd do because of acoustics' But I'd like to think that somewhere along the journey there is a solution that is both aesthetically pleasing and acoustically workable. I think that is where it'll get to. I don't think we will ever get to the point where we will say 'this ceiling is the only ceiling that works acoustically'.

AMDS: Ok

AN: It relates to the number of seats and a whole lot of other things. We also have to remember where this is and what this building signifies and stands for. It is not just about acoustic but about holistic design

AMDS: Yes

AN: In acoustics, and services and structure

AMDS: I was talking to Richard Johnson and of course he is very fascinated about Utzon and the whole project as it should have been. And he said that he is very surprised that no-one ever build a hall like this, like Utzon envisioned it. Would you say that you are as well or?

AN: that nobody has build a hall of this shape?

AMDS: Yes, with the radial geometry and the curving of the ceiling that leads into the procenium

AN: I am not surprised

AMDS: No?

AN: It breaks so many of the rules that acousticians sort of heralds. It doesn't surprise me that a new scheme has never got of the blocks. Because this one has been so publicly criticised for its acoustic it takes a very brave client to turn around and say we should repeat this just because of the... Not because of Utzon but because of what has happened after Utzon. It would take a very brave person to say that we should copy the interiors of Sydney Opera House from an acoustics perspective.

AMDS: But has it really been criticised acoustically... because did people really know?

AN: Oh, forever, forever. It is very widely written, very widely.

AMDS: But that is...what I found from Jordan himself is not really that well based on what actually happened in the last part of the project, that was more the first couple of proposals by Utzon. Would you say that also the last proposal by him [were widely publicly criticised]

AN: by Utzon? No, because it was never build, nobody has ever had the opportunity to criticise it.

AMDS: Okay

AN: What people criticise is what people see now and hear now. They don't like the sound, it is a bitter disappointment to what they see outside. The interior architecture is a bitter disappointment to what you see outside, to those who are aesthetically minded but whether or not Utzon's original designs would have worked I don't think anybody has ever given that sufficient sort of credibility in terms of looking into it because it was never going to be build.

AMDS: No.

AN: I would always refrain from looking at the past, always look to the future. So this is about the future. We unlocked the first bolt on this project which was the tie-beam once Arup found that we could remove that tie-beam, that

auditorium was never going to work. Utzon's opportunities came in front of him until that happened that auditorium would never have been a decent auditorium because there were so many things that were wrong with it. This was his opportunity to put it right and that is probably the most exiting thing because if we couldn't do that none of us would be talking about it.

AMDS: No.

AN: All there would have happened was a lick of paint but everybody would still say 'oh, it's not very good in here is it?' So I would always look to the future and say what is it that Utzon and Arup and JPW can do now to make the best of what we can.

| | |
|---|---|
| Interviewee: Andrew Nicol, Director Arup Acoustics Australasia [C] | |
| Interviewer: Anne Marie Due Schmidt | |
| Date: June 28 2005 | |
| 5 | Location: Meeting room in Arup Acoustic, Sydney Office Notes: This interview follows a design meeting of another project "The Hastings Project" and therefore to some extent compares the Sydney Opera House project to this. |
| 10 | AMDS: Has the Hastings project been easier than the Opera house one? AN: When you are ready [pointing to the tape recorder]... AMDS: Oh, it is ready. |
| 15 | AN: has it been...yes, yes it has. It is an easier theatre it is much simpler, it's a new theatre so it's not a refurbishment, so that makes a difference, less seats, so we're not constantly trying to force lots of seats into a small space so that helps a lot. And...so we're not so bound by complex, ehm [philosophical] geometry. You know the radial geometry from Utzon |
| 20 | AMDS: yeah, exactly AN: ...is very...ehm...it's very powerful in the design of what we are doing, so it limits our flexibility |
| 25 | AMDS: yes, you can't move around so easily AN: yeah, whereas what you saw this morning [referring to Hastings meeting] was very much a case of an architect who has some ideas which are very ehm.. they are picking up on what we're suggesting. So we, we...this is our design, they are taking in and they are actually working with the ideas and saying 'yes, we can make this work'. |
| 30 | AMDS: yeah AN: so from that point of view it is a lot more straightforward. |
| 35 | AMDS: yeah AN: and we are in a stage in the project where things are clicking into place and what you saw this morning was most of what we were wanting to design being accepted and accommodating by every one else around the table. |
| 40 | AMDS: yeah AN: so it was quite straightforward from that point of view. AMDS: yeah exactly. It seemed like 'ok, this and this and that' |
| 45 | AN: But it also helps...you saw, the way we did it was we were sending round design notes, so we issued five design notes last week. AMDS: yeah, I saw some of them, or I saw one of them ... and that's the normal procedure as well or? |
| 50 | AN: it is something we've been trying ...in this project we're going to do all of it like this. We done it, we did it on the Utzon - on the Opera House... AMDS: ok AN: ...for a while AMDS: yeah |
| 55 | AN: Ehm...we had our Acoustic Design Principles which we spoke about before. This one we decided that we'd take a section of the design and just concentrate on that...and the key in it, describing what that is doing for us acoustically and why it is important. So that ...the..the..ehm the architect and the design team and the clients says 'ok, the reason why they are being so strong about this is because they need to do it'. |
| 60 | AMDS: yeah. AN: and what we've done in the past is we've written an acoustic report which had everything in it. And first of all that takes a long time to write that report because just... it has so many elements to it. So until you are happy that you've got every element right you can't send the whole report. Whereas this we can pick a subject which is a key subject, write about that subject and issue it. |
| 65 | AMDS: ...send it off. Ok. AN: so it has actually worked quite well and you saw how well the architect responded to it today |
| 70 | AMDS: yes, exactly. And also...the full report probably also always came too late in a way? AN: yeah...yeah...yeah. |
| 75 | AMDS: Ok. AN: So we're keeping going, keeping pushing. We've got three more we'll issue this week. AMDS: Ok...and that's the end of it, you think or..? |
| 80 | AN: That's...that's us putting all of our design onto the table AMDS: ok, playing your cards [laughing] AN: we've played our cards, yep, I like that, and then they'll respond to it. And there'll be some negotiation |
| 85 | AMDS: yeah AN: they'll come back with something, we said it has to be that, they'll come back with this, we say that, you know it'll change along the way AMDS: ok AN: they are good architects to work with |
| 90 | AMDS: yeah, it seems like a very happy collaboration. But... ehm...at one point today there was also a point in the meeting where you were explaining something and it was probably about the last design note that you had issued because the hadn't seen that before, where they went a bit blank, I mean where they were like 'hmm' [signalling gazing] and you were talking and explaining and everything and they were just 'okay, we'll look at it later' and it got me thinking whether they take in what you are saying as a principle or they're acting upon what you are telling them to do? I mean, because you point to the drawing and say 'it should be more like that', do they necessarily understand why it is supposed to be like that? |
| 95 | AN: Not without reading it. I think that's...I think what you saw was...we were just picking at...there was one design note which was finished this morning. I have been away for the last four days, so my colleagues have been doing the design notes and issuing them for me. This one didn't get issued because they had a question for me. |
| 100 | AMDS: Ok, so you had to answer that AN: so when I arrived here this morning, they asked me the question, we resolved it and it went out. But then they hadn't read it before the meeting whereas all the other ones they'd read before the meeting so they'd read why it |
| 105 | |
| 110 | |

- 115 was that we needed to do something, ehm...and what it was that we needed to do. So they were able to absorb it and so they felt educated. People don't like being put on the spot saying 'here's something, make a decision', that's not very good. People can't react very well to that. So that was a
- 120 good example of how to do it and how not to do it. Yeah?
AMDS: yeah, exactly
AN: so the last one didn't work as well. Next time we meet they'll have read it
AMDS: yeah, they'll know what it's about. Ok. But that
- 125 doesn't necessarily mean that the next time they were going to do an auditorium they would be able to do it without the help, you think?
AN: no [shaking his head]
AMDS: no..
- 130 AN: well it's a question...I've often wondered, particularly when I was working overseas in London, where we worked on many projects with architects like Foster. And we'd give advice and ...ehm...they'd understand it, take it onboard, go away and draw it and we'd correct it and you know,
- 135 eventually we'd get it right. And it could be any subject in acoustics, it didn't have to be an auditorium and you'd do it again and you think 'well, we'd worked with these people two, three times, why don't they just do it themselves?' - which was what architects used to do. And of course what
- 140 it is, is that the responsibilities of an architect has been completely...ehm...diluted...and so their risk is spread across consultants
AMDS: Yeah, true
AN: ...so they may not necessarily need to know the
- 145 answers but they need to have somebody who is responsible for taking the decision and ultimately, if something goes wrong, somewhere for the architect to point their finger of blame at. And it doesn't necessarily have to be the architect. It could be the client, it could be a project
- 150 manager, collecting a team of people and all they are doing is they are transferring their risk so that they don't have to make any decisions, they don't have to be responsible for anything and other people are fully responsible. So that's why they keep coming back for advice.
- 155 AMDS: Yeah, because they need somebody
AN: because they need somebody to blame, unfortunately
AMDS: yeah
AN: it's not that simple of course
AMDS: no of course not but it also, I mean, I see some
- 160 difference in the way...ehm... the Utzon project was done and the projects today are done - not necessarily the TZG but projects generally - that you have this ...you can almost see in the projects the line between the specialists...for instance here the shape of the auditorium itself is defined
- 165 by the structure and there is the acoustic ceiling....ehm... where if you were the architect working on all of it you'd probably try to integrate some of the thing or try to make it the same...but, yeah...it is quite an interesting thing in architecture that it becomes apparent in the result
- 170 AN: yes, yes, yes
AMDS: ...ok, let's see what else I had [looking in questions].
-Yes...'the same procedure'...With the paper flow you tried to do it the same way as well and youbut...I didn't catch that; did you issue those design notes on the Opera House as well or did you try to collect them in the report? 175
AN: ehm...it was slightly different...we didn't issue...in the same way that I've done for this one [Hastings] ...each element. What we did is that we had workshops
AMDS: oh, yeah
AN: with Richard Johnson and Jan 180
AMDS: yeah
AN: and we would cover aspects of the design, so we would do a little bit here and a little bit there and we wouldn't write as much down. It wasn't as much as a transaction, it was more a...one on one like we are having here, 'this is how we want to design it' and 'this is what we want to do this'. So we would draw...and it would be a sort of working thing. Richard would explain what he was looking for and we would explain what we were looking for and so there was an interaction as opposed to a transaction. That was quite different. 185
AMDS: yeah
AN: and that suited their way of working quite well. We did set out one document, we set out some Design Principle which what we called the Acoustic Design Principles in opposition to the Utzon Design Principles. 195
AMDS: yeah
AN: And they were rules which we wanted entrenched in the design. And they were things like volume, width of the auditorium, size of the orchestra pit, distance to the balcony...just a whole range of things, nine pages of things which we...those were our rules
AMDS: yes
AN: and there were some flexibility in some of the aspects... but we wanted the architect to work - or Richard and 205
Jan and Jorn to work - with the set of rules in mind and understanding why.
AMDS: Yeah
AN: So the understanding why was done by discussion and...ehm...you know, we would have a conversation about 210
the importance of acoustics but it was...it was already known. All of these architects; Jorn, Jan and Richard all know the importance of acoustics in the opera house. It was just reinforcing that to them. So it was done slightly differently... I wouldn't say that either way is...is...is right or 215
wrong.
AMDS: No
AN: It was what was right for the people we were working with.
AMDS: And probably also there is a difference in the 220
character of the projects, I mean for an Opera House it is kind of obvious, the need for acoustics
AN: yeah
AMDS: ehm...as...not opposed to...but perhaps in a performance space as the other one the acoustics is 225
perhaps not as obvious.
AN: yes, it is topgrade and very good [indicating on an imaginary vertical scale how they are positioned].

AMDS: yes, exactly

230 AN: the Opera House is a world class auditorium that will be judged on its finest acoustics – among other things – this auditorium we’re designing here is...they want it to be one of the best in New South Wales, they want it to be...as good as Sydney Theatre so they want all of these attributes but

235 they don’t want it to be a world class

AMDS: no. And it is also something that is for the community and very ehm...

AN: not the elite opera goer or ballet goer...yeah

AMDS: Ok. So...I know we’ve talked about this but...how the

240 architects work today as opposed to before where they had all the responsibility.

AN: Yep

AMDS: ...so would you also say that that gives you more influence on the projects?

245 AN: yes.

AMDS: ...

AN: Sorry I should let you finish your question

AMDS: no, no. That was actually it.

AN: We’ve always had influence over certain types of

250 projects, particularly where acoustics is...is, is of critical importance...ehm...and there has been a growing respect for acoustic consulting as a discipline over the last twenty years.

AMDS: Ok

255 AN: Fifteen, twenty years...It started as an engineering type of focus but shifted much towards design and influencing design. And the strong acousticians that are working around the world now are the people who actually are able to design and draw rather than just to be able to talk about

260 numbers.

AMDS: yeah

AN: ehm...but nowadays I think we have even more ...scope to lead in the design...and the architect to follow. Eh...some of the things we were talking about today were

265 quite architectural but they are beneficial to the design acoustically and architecturally

AMDS: yeah

AN: but I was making them on behalf of the overall design but driven by our experience...ehm

270 AMDS: and even today you were making comments on some of the aesthetics...this boxboom ehm..

AN: yes.

AMDS: Boxboom..is it?

AN: A boxboom, yes

275 AMDS: where you said that it might be very heavy to look at.

AN: yes

AMDS: that surprised me, actually. That you would go into...their field in a way.

AN: Well that’s...when you work with an architect that has

280 not designed many theatres before...ehm...and we’ve...I’ve designed many theatres. I have an amount of experience which I can bring into that. Now I can make these comments ehm...and sound authoritative because I have experience or I can make the comments because...ehm...I

285 am just being a bit cheeky, yeah? I make them because

I... often step out of my role as an acoustician and do a lot more about the design, the overall design

AMDS: Mhh

AN: So rather than going through the process...I’m...as a character I’m a little bit impatient. If I want to get to that

290 point there, I don’t like doing this ...exercise...of going back and forward and then eventually getting to there. So rather than them sending me something and me saying this, sending it back, you know going back and forward,

295 ehm...I like to point them in the right direction as soon as possible...if it’s important...If it is something they need to discover themselves for them to really truly accept it and that is a different tactic. But on this occasion when...if they had actually done a view of the proscenium with that

300 element...ehm, you know...

AMDS: yeah, they probably would have realised themselves

AN: [getting up and drawing a view of the proscenium on the whiteboard] yeah....they were looking at something like this....where this element were going to impose like this

305 and there was the ceiling would come down like this....this element here was really solid and that would just stick out because the rest of it is quite light

AMDS: yes with all the panels

AN: all the way around here [in the rest of the hall]

310 AMDS: yeah

AN: and it was going to look really heavy. So that comment....they can throw away the comment ...I was naughty today, I told them to do this [tilt the proscenium wall in order to create a funnel out to the audience] and I knew they wouldn’t want to do that, okay? But that is quite

315 important to us so what I want them to do is that I want them to bring that element in and then do that [break up the wall in two sections]

AMDS: yes break it up

320 AN: to get that [the broken wall with the second one funnelling more than the first], which was what we needed, we had that [first option with the full wall] plus that [broken option]. And they didn’t want that, so they said themselves ‘we’ll move that’, so I was playing a little game with them to get what we wanted which was this surface here [the one

325 closest to the stage] so....it worked quite well!

AMDS: yeah [laughing] you got what you wanted

AN: yeah...but again...that would actually help the overall design from their perspective...they’ll, they’ll see that.

330 AMDS: yeah

AN: and when they draw this, they’ll think ‘yes, this actually looks better, it looks lighter’

AMDS: yeah

335 AN: And I made a few comments like that through the meeting, you probably saw that.

AMDS: yeah...so you think also that the way you are communicating is quite important. That you need to draw and...and they need to understand why you drawing what you are doing and...

340 AN: yeah.

AMDS: yeah

AN: I see...I see an acoustic consultant as part designer

and part engineer, okay? This is the sort of design part of what we do [pointing to the whiteboard to indicate the
345 proscenium discussion] and some architects like it and others don't
AMDS: yes, I can imagine that
AN: and the engineering side of it is the bit about the weight of the walls, the sound insulation, making the room quiet.
350 All those sorts of things. That's the engineering bit. The thing that actually contributes to the look and the sort oftextual things...that is what we can influence...and that's the role...that's where Arup is a practice that tries to step ahead of other acoustic consultants, we are design focused
355 practice so we say in our proposals that we are a design focused practice. Well, if we say that we should be able to do this [pointing to whiteboard indicating 'drawing']. Now I'm not very good at drawing
AMDS: but it works [laughing]
360 AN: but I have some who does it for me.
AMDS: ok
AN: we have an architect who works for us. We have a number of architects around Arup Group so the drawings are done by an architectfor us.
365 AMDS: yeah. But even those kinds of drawings [pointing to the whiteboard indicating 'rough sketches'] are quite important to explain...
AN:...little things like that...yeah....so when they come in a formal document, they are there. I actually quite like to do something like that, so you can see what it is that you draw.
370 I don't draw very well, but I can explain by just scribbling that
AMDS: many architects don't draw very well...
AN:...they all use computers now..
375 AMDS: ...yeah, as well...Ok. Ehm...yes, then there was. This is about the Opera House....ehm...I spoke to Norman Gillespie
AN: oh good
AMDS: and I don't know whether he contacted you?
380 AN: Ehh, when did you see him?
AMDS: that's many weeks ago, actually....ehm...four, I think.
AN: I can't remember, he might have done. What about was it?
AMDS: Because I was talking to him about the documents, whether I could get access to any or not and he said 'sure you can – with some of them' so he asked me to try and pinpoint which ones would be very important to me and then to ask you whether it would be possible
385 AN: ok, right
AMDS: But he also said that he would contact you and say that it would be alright.
AN: okay
AMDS: so if he didn't do that I need to get a hold of him again
395 AN: no, he hasn't contacted me. He has been very busy... they...ehm...they are still trying to get the money for the building.
AMDS: yeah, to push it...
AN: And I think Jan is around at the moment, was it last week or this week
400 AMDS: ...oh, I didn't know...
AN: ...Jan is around so he's been busy with him.
AMDS: That's fine
AN: So contact him again and I'm happy to give you whatever you need. How much longer are you here for?
405 AMDS: I'm here till the eleventh of August
AN: Alright, so plenty of time
AMDS: yeah, that's fine. Ok...we've just got nine minutes more...
410 [about the Utzon room]

| | |
|--|-----|
| Interviewee: Niels Jordan, Jordan Acoustics, Acoustical consultant on the Sydney Opera House 1966-1973 | |
| Interviewer: Anne Marie Due Schmidt | |
| Date: November 24 2004 | |
| 5 Location: Jordan Acoustics | |
| Notes: | |
| AMDS: I am writing a PhD... let me begin with: I am educated at Aalborg University at a new education called | |
| 10 Architecture and Design which is a Master of Science degree and attempts to combine the two aspects...to get the benefit from both. | |
| NJ: Yes.. | |
| AMDS: And that is also what the PhD is about – how to work | |
| 15 with the two professional fields in architecture. | |
| NJ: That sounds really exciting because when I graduated architects and engineers were to opposing worlds. They knew they needed each other but they did not know how. The architects I know they have nothing to do with sound. | |
| 20 They don't think about sound at all. They think in visions, how it looks, in colours and so on but they don't know anything about what is going on in the ears. | |
| AMDS: And actually it is strange or sad because the aural experience of a space is just as great a part of the architecture as everything else. It is not only a visual | |
| 25 experience. | |
| NJ: Definitely. If sound and sight are not in harmony one feels cheated, like something isn't riming, right. Then something is wrong. So I think it is a really exciting aspect to combine engineering and architectural disciplines. It certainly is. And in that respect one can say that acoustics has fallen between two stools. The engineer has not really wanted to acknowledge it because they don't know enough about it – and are not taught enough about it. And the | |
| 30 architect is completely unwilling to acknowledge it – and they are not taught anything about it. And that means that many times the question of acoustics is a stepchild that is introduced too late in the planning- and detailing phase. And many times it becomes half-measures and changes afterwards. | |
| AMDS: or even demolition | |
| NJ: Yes actually. | |
| AMDS: I would like to talk to you for three reasons. Firstly, simply because of your profession as an acoustician. | |
| 45 Secondly, in connection to the Sydney Opeara which I am going to use as a case in this project about the collaboration between architects and acousticians. I am going to follow the work down there in connection to the small auditorium that is being refurbished but of course I | |
| 50 am also going to investigate the historic part of it, so your firm's involvement in the case is interesting. And then lastly in connection to your work on Odeon because I have been working with CATT that might be called the competitor. | |
| NJ: You don't know Odeon? | |
| 55 AMDS: Yes, I know it from a presentation but I haven't worked with it myself. But it is basically the same thing as CATT as far as I can see. Except that it has more functions. | |
| NJ: Yes a lot more. | |
| AMDS: A lot more? | |
| NJ: And it is more user-friendly | 60 |
| AMDS: Yes? Because CATT is not very user-friendly | |
| NJ: No, that is not really it. | |
| AMDS: Ok, if we begin with the Sydney Opera. I don't know is it something that many comes and asks you about | |
| NJ: Well, yes... | 65 |
| AMDS: ...and is it difficult to talk about? | |
| NJ: No, no. I am very enthusiastic about the Sydney Opera House and the whole project. It was my father who began this firm back in the forties when he was involved in Denmark's Radio's Concert House, the concert hall | 70 |
| up at Rosenørns Allé, the studies and so on. And then he became self employed in 45 and worked on the Tivoli and the Aalborg Hall and a number of other rather big projects. And then he got involved with Utzon on his project proposal for the Sydney Opera. And therefore he was also, naturally, | 75 |
| consultant, acoustician for Utzon and the Government back in 56. So I have had it close by all my life, actually, and I was in Sydney in 70-73 myself. | |
| AMDS: Yes, I could see on your resume that you had been out there. | 80 |
| NJ: Yes, we were living out there for three years. But that wasn't in Utzon's time. That was after he had left the project. And it was for the new Australian architects from 70-73. At that time I was a young lad and acoustician. So it was some experience; to be in the architectural office and be involved in advising the architect and the engineers on constructions and ventilation during the whole process. And also to be supervising at the building site – they were building at the same time as they were detailing the project. | 85 |
| AMDS: They began building quite early, right. | 90 |
| NJ: Yes, and then also the last phase with testing and handing over the project. It certainly was a good training post to have. I came down there immediately after finishing in the military. And then we were there for three years. So it was out there Tanja learned to speak English – or Australian. She actually did – real Australian! | 95 |
| AMDS: Real Australian accent | |
| NJ: Yes, exactly. But it didn't take more than three months after we came home and she started kindergarten then she wouldn't talk English anymore. There were a few words like if and when that stuck but they have also gone now. Since then the English has been from her studies in England and New York and so on – and now it isn't Australian anymore! | 100 |
| AMDS: I understand it as if the demands for the auditorium were changed during the process. From what the task were first, you were during a number of investigations where you found out that it was difficult to fulfil. | 105 |
| NJ: Yes it was a politically sensitive process because Utzon's task was to create a combined concert hall and opera hall. It was to be used for both purposes and to have at least 2800 seats. And that is a large hall. That was positioned under the larger shells. And under the smaller shells they were to have more intimate facilities for theatre and there were other things that were important. | 110 |

- 115 And that gave him a lot of problems and it was probably what ultimately got him kicked out because he had such difficulties getting that number of seats without placing the audience on the stage. It was difficult to make it work. And then he developed his last proposal where all the
- 120 audience – in the concert hall situation – was sitting was sitting in front of the stage. And there he was short of the 2800 seats. And then it became political. The opposition found out that it was going to be too expensive - and it was really expensive – and that he worked untraditionally
- 125 with mock-ups and prototype development. And then the Government changed and it was, what should we call him, a very staunch gentleman, a former school teacher, from the northern New South Wales, who became the Minister of Public Works and he simply wanted to place Utzon under
- 130 administration. Their chemistry didn't work together at all. AMDS: That wouldn't have worked
NJ: No, and then in the end Utzon threw in the towel and said "if I can't have it like this I'll withdraw." And he just said "can I get that in writing?" And then Utzon was in a dilemma
- 135 because it wasn't him who had the contract, it was Arup's, who were the construction engineers that had it because the Government from the beginning had said that they wouldn't give Utzon the contract on it all because he was an unknown quantity, he hadn't got any experience. Therefore it had to be the engineers who had it. And there Utzon had
- 140 his dilemma because Arup's said "well, we have never left a building site before completion" so they wouldn't dream of leaving it with Utzon. And all the engineering firms, Steensen and Varming, [Seuden and Sørensen] and dad, they all had contracts with Arups, so they couldn't do
- 145 anything. And then he came to stand alone. AMDS: But what about the German acousticians?
NJ: Well, they came in later. Or rather, they were engaged by Utzon. Firstly, dad was the only acoustician until the beginning of the sixties.
- 150 AMDS: I've got 61 here.
NJ: Where he simply... we made model testing... built models in 1:10 and tested them and we couldn't make his designs give the right results. Utzon couldn't live with that. Therefore he hired another acoustician who couldn't get the
- 155 right results either and then a third acoustician was hired and I think he ended up having three acousticians. Dad, then, was pushed aside. And the second – what was his name – a famous German one...
AMDS: Yes, Lothar Cremer
- 160 NJ: Cremer, yes. And then Gabler was attached and they felt in the end that they had come to a solution that they could solve
AMDS: But it was changed a lot so it wasn't the original proposal that they worked on?
- 165 NJ: No, no, it was changed all the time. I don't know... have you seen the book dad wrote about it?
AMDS: No, I haven't
[Jordan is looking for the book]
- 170 NJ: It is out of print so it can be difficult to find but it should be in the university libraries. There is a chapter on the Opera House, about how it all evolved.
- AMDS: All right. What I have read is Philip Nobis' thesis about the design development of the auditoria.
- NJ: That one I don't know. Oh, it was him who made the 3d model... Nobis, yes, all right, I've heard about him. He goes through it all. 175
- AMDS: Yes, so from that publication I know the development of the auditoria but I don't know the acoustician's side of it.
- NJ: No. Where have you got that from? 180
- AMDS: It is from Philip Nobis himself.
- NJ: Oh, you have been in touch with him?
- AMDS: No, but my supervisor has
- NJ: ..[Reads a dedication to Architecture and Design on the title page] 185
- Oh, yes, Department of Architecture and Design. Yes, ok, is there any more copies?
- AMDS: Not really, not in Denmark and not in print and for sale but I can take a copy for you if you'd like?
- NJ: If you would do that I would appreciate it a lot because he continues longer than I know the story – after 73 we haven't had much to do with it. I remember he had a picture. Were you at the exhibition at Louisiana [an exhibition about Utzon]? There he had a picture from the models... I don't know whether you remember that? 190
- AMDS: Yes it was, what was it called...? Geisha's wig!
- NJ: What do you call it?
- AMDS: Geisha's wig. The wig of a Geisha, they called it. I think it was the one where there were so many problems because he used concave surfaces. 200
- NJ: Yes. Here [showing a picture of a large wooden model with a man, Vilhelm Jordan, sitting in it] Here he has a picture of one of the later models.
- AMDS: Yes, this is one of the latest, right?
- NJ: Yes, and there he has put in a picture of one of the models. That is my father's models and that is my father. And it is Jørn Utzon himself who has taken it. But they were accredited to the Germans. 205
- AMDS: Argh, that is a shame
- NJ: Yes, it is a shame. And it is actually Nobis who has brought is forward and it probably because Utzon has not wanted or has been too old to remember that this was my father's models. And it is one of the models we tested. And we couldn't make this design work. One of the things we did was to hang a number of vertical baffles up to prolong the average reflection length. 215
- AMDS: Prolong it or shorten it?
- NJ: Prolong it in order to keep some of the reflections longer. This design without the baffles was much too projective so that all the sound was projected into the heads of the audience. That means that the acoustics wasn't developed in the room, the sound wasn't developed. 220
- AMDS: You only got it from one angle?
- NJ: Actually you only got it as direct sound. And that is even more so due to the whole design. When you sit in a fan-shaped room where you have a reflecting surface that is directing the sound towards the people – then it is 225

| | | |
|-----|---|-----|
| | absorbed. And then the space isn't alive. And that is where the modern auditoria distinguish themselves from the classic halls. Because in the classic shoebox-shape with the high ceiling the sound is oscillating and then the sound to people. Where this design – and also the Radio House concert hall and many of the other fan-shaped halls – direct the sound much too directly towards the audience and thereby you lose any sensation of the auditorium itself. | |
| 230 | AMDS: Ok! | |
| 235 | NJ: And that trick [the baffles] was a way to prolong the reflection length of the sound reflections so that they weren't projected out directly. And that was successful – it was a way forward. And this was showed in our models. Even though it was fairly primitive models in 1:10, you can see there is no real finesse to them, the measuring technique was so well developed, however, that you could trust them. But he [Utzon] didn't like them [the baffles]. | |
| 240 | AMDS: No, that was probably somewhat different than he wanted | |
| 245 | NJ: Therefore my father was sidetracked. He just didn't ask him about anything anymore and he didn't send any more drawings. What can you do? You can't do anything. . | |
| 250 | AMDS: No, nothing at all | |
| | NJ: And then the Germans took over. And then you can see here [turning over the leaves in Jordan's book] | |
| | AMDS: ...[pointing to the Geisha's wig proposal in the book] that was the one I meant.. | |
| 255 | NJ: Oh, yes, the original...there it started... [turning the leave to the competition design] and this was the design for the competition. | |
| | AMDS: Yes, how was your father actually involved with the competition? Was it drawn by him at all? | |
| 260 | NJ: No, no. Dad didn't have anything to do with the drawings but he – how to put it – he advised Utzon regarding the text and what to emphasise and so on. But it was Utzon's competition project fully and entirely. My father wasn't involved with that. It later came apparent that the design couldn't fit under the shells. The shells as they were originally – I don't know whether you remember...? | |
| 265 | AMDS: Yes they were very low and wide | |
| | NJ: Very low and wide reaching sails and that was the first problem they ran into. That Arup's couldn't make them stand up. It was useless how they were floating in midair without any columns or anything. And what happened? They had to push them in and raise them higher to get the forces down. And that resulted in that area that we have here [points to the plan of the competition indicating under the sails] was reduced. And then the problems began in earnest because then it became difficult to seat all those people. | |
| 270 | AMDS: Yes, all right | |
| | NJ: And then he began making all the variants with the curves and so on. And this was what it ended with. And what happened...I don't know if I am jumping too much ahead...but anyhow, at the point when Utzon gave up he had three acousticians who did not agree and he had an engineer who wouldn't leave the building site with him and | |
| | he had a political opponent who wanted to put him under administration because of the economy that just ran amok. And this they knew from the outset because they had drawn up an unrealistic budget to get the project going. | 285 |
| | AMDS: Yes that wasn't too surprising | |
| | NJ: It wasn't too surprising. But now they had been elected on getting the situation under control and the manner that Utzon worked with using firms to develop prototypes and test them and so on, that was completely unknown in Australia. You couldn't do something like that. You should design and then collect bids from a selection of companies and get it produced. So that was also one of the oppositions. | 290 |
| | AMDS: He wanted to choose who should get the tender and then make them develop it? | 295 |
| | NJ: Yes and develop it with them. But he wasn't allowed to. And then he was removed from the project and then they chose a couple of Australian architect – the design architect Peter Hall and the administrator architect Lionel Todd and the building architect David Littlemore – to be the new team. They had to...Arup's was still there and Steensen and Varming was also still there and then they had to choose an acoustician. And they chose my father. They didn't want the two Germans. And then my father got a theatre technical expert from New York introduced that he had worked with in the Metropolitan Opera and the New York Theatre – from that my father knew him. | 300 |
| | AMDS: All right, who was that? | |
| | NJ: What was his name...it says so somewhere in the book. I can't remember – I'm not so good with names. So the new architects agreed that it was dad who should continue and then this guy joined as well. And actually they began by thoroughly analysing the project's idea and concluded that it was a bad idea to combine opera and concert in the same auditorium Dad had been saying it for a long time. Acoustically it is a bad idea but functionally as well because you can't have opera and concert the same night then. So it would limit the use of the house itself. And then they came up with the idea of saying "All right, the Australian Broadcasting want 2800 seats or they can't make ends meet financially with large international stars etc. They will get a large hall – purely concert hall. And then we'll move the opera under the smaller shells." And that naturally was a handicap for the opera. Definitely. Because it isn't as large. | 305 |
| | AMDS: No, that is much smaller. | 310 |
| | NJ: I don't know...have you been out there? | |
| | AMDS: No, not yet but I'm going in February. | |
| | NJ: Oh, in February...so it was a huge decision because all the scenery and the construction of the stage tower was completed – it was already there. So they tore it down and drove it to the dumping ground, that didn't make it any cheaper! But at least they knew how to build the shells and they were busy doing it when I came out there. And then they also knew how much space was available under the shells. And therefore they started working on pulling the podium into the front of the auditorium and get the | 315 |
| | | 320 |
| | | 325 |
| | | 330 |
| | | 335 |
| 280 | | 340 |

audience along the sides and on the choir balconies.
 AMDS: But that was conditioned by that you had moved the stage tower?

345 NJ: Exactly. Otherwise it wouldn't have been possible. Utzon had cut the auditorium off here [showing the line between the stage and the audience] and said that the audience should all sit out here. And there simply wasn't enough space. Now it was possible to design a hall solely
 350 for concerts and we did models – both here at home and out there were models of the two auditoria which I've worked on testing. And we found this [pointing to a picture of the current concert hall] that could give really good results. We had maintained the shoebox-shaped hall on the
 355 tall part that runs all the way through – then we could get the reverberation that we needed – and then we pushed the audience into the sides so that the shells came straight down. It was rather tricky just to get the geometry to fit. And you can see from this picture here... [finding picture of
 360 Utzon's proposal] ...look that's the last of Utzon's models, right, with these large mill wheels which – and you can almost read it out of the shape – much too quickly throws the sound into the heads of the audience. Whereas here where we take advantage of all the volume we could get
 365 and get tall walls that are almost parallel – and as you can it is the shells coming down. They limit how far you can go. AMDS: So the space goes right to the top of the shells... NJ: The space simply takes advantage of all the volume that is available, right. And that naturally has the effect
 370 that the orchestra is positioned rather much into the open landscape. But that we could compensate for by having a series of reflectors over the audience so that the orchestra got all the energy back that they needed to get a decent ensemble.

375 AMDS: In order for them to hear each other... NJ: And at the same time we got the volume that we needed to make the acoustic pattern that we wanted. And I think that was an incredible experience. To listen to test concerts in the finished auditorium. And people were highly
 380 excited. AMDS: Yes, it is still very famous NJ: Yes it is very boasted of. They are very happy about it. I know they have a chief conductor at the moment that are not fond of those reflectors and doesn't think they
 385 are efficient enough. And that might be that they aren't because there one is in a level of detailing that can not be tested in a scale model. AMDS: Yes, then it has to do with the musicians feeling of it when they are sitting there.

390 NJ: Yes, but you can do it today with Odeon. There you can represent the sound energy that returns to the musicians, its distribution over the podium and the sound energy that leaves and strikes the room. If we had had Odeon back then we could have designed the exact series of reflectors.
 395 And that was actually what we did in the Radio House Concert hall at the refurbishment that took place in the mid-eighties, late-eighties, where we started out with the Odeon calculations and could design this array of reflectors

that replaced the old ones and optimises them. At the same time we got sideward reflectors so that some of the fan-shape was compensated for. Do you know the project?
 400 AMDS: I have looked at it briefly but I don't know it thoroughly NJ: No, well it has been developed so thoroughly now that there is full satisfaction with that hall now. Even if they are
 405 getting another now. AMDS: Yes. That was a full fan-shape, right? NJ: Yes it was a very pronounced fan shape. And that was unfortunate, they knew it but at that time the architects had more to say that the musicians and the engineers and the
 410 acousticians. Today they haven't. AMDS: No, I think also today there is more attention but on the contrary on can argue that some places it is somewhat of a pity. For instance in Aalborg where they are designing the House of Music and the manner they are working
 415 with acoustics is really to play it safe by choosing the shoe-box which is a fine prototype but it just hasn't been accommodated much so it seems like it has been placed in the building and the project has been sketched up around it.
 420 NJ: But did you see the competition brief? That hall was designed before anything else! It had to be like that! And it was because Aalborg Municipality's adviser who was Norwegian, who was called... eh, I don't remember...
 425 anyhow, a Norwegian from Oslo, who had been on a study trip to a number of halls that Russel Johnson from Artec had made – among other the one in Lucerne. And he was simply thrilled about it. And when Aalborg Symphonic Orchestra at the same time had a guest conductor from
 430 Singapore, which has just gotten a concert hall designed by Russel Jonson and Artec, everything fitted together. It had to be one just like it. And this firm, Artec, they one do one type of auditorium, this elongated, oval shape with small balconies in several stories, going upwards. And by
 435 now there is numerous examples f them – both in America, Birmingham and Lucerne and now lately Singapore and now Aalborg also. He is the acoustician on it. And I think that is...that's sad.

AMDS: Yes, if can only be one type of auditorium
 440 NJ: And then he has these completely hopeless ideas about echo rooms and a giant, massive reflector weighing several hundred tonnes that needs to be able to move up and down over the hall – and it doesn't bloody work.
 445 AMDS: The echo rooms I think they have given up on NJ: Well that was sensible. That was bloody sensible. In Europe or at least in the North and Germany we have a completely different take on acoustic detailing. We'll go in a construct our own tools – for instance Odeon – to demonstrate and measure and document what we achieve
 450 by these things. The Americans they are floating and explaining and talk the hind legs off a donkey, they sell the product but they have no idea why it works as it does. AMDS: They know it works and then they copy it.
 455 NJ: They never do measurements; they have no idea how to do it. They never use any detailing tool such as Odeon and

so on. It is pretty scary.
 AMDS: But what do they do?
 NJ: Well they have found this oval shape that works, they think. And then it is just that one they'll use. WE can't
 460 measure any difference from the echo rooms. We've attempted to measure it but we can't measure anything! It is a scam! And that giant reflector; when it comes down to it, you can't use it. It needs to be in a set position because else the ones sitting in the balconies can't see the orchestra and if they can't see they can't hear, right.
 465 It is nonsense and now they are doing the exact same thing in Stavanger. It is also a Russel Johnson/Artec hall – exactly like the one in Aalborg. There is only one design and that is primitive.
 470 AMDS: So that is where equally the difficult and the exciting emerges... because that is where you come in to the picture, Jordan Acoustics, and looks at the proposal from the architect and develops it?
 NJ: Definitely, definitely. And that is why increasingly I am
 475 involved in the competition stage so that we'll get the shape of the hall that we know works and that we can detail later on. But those programmes that were written for both Aalborg and Stavanger, there we were a step behind because it said in the programme how it had to be. And
 480 then there is no competition jury that will choose anything else if it is conflict with the competition brief, right. There they were more visionary when they chose Utzon's because if there was something that he did, it was to break the rule by placing the halls next to each other. And he was able to
 485 win never the less. And that was because they had a strong architect in the panel, was it Saarinen, and when he came to Australia to participate in the jury they had taken a hundred of the submitted projects in a pile – collected the ones that they wanted to choose between but he said
 490 "no, I want to see them all". And from the bin he got Utzon's project and he said "that one, that is the future, that is the one we should have". That's impressive!
 AMDS: The story goes that Utzon's project was discarded because he had used leaf gold on the panels and you
 495 weren't allowed to, they were only to be in black and white.
 NJ: That one I hadn't heard. I only know that part about Saarinen who took it up from the paper bin and convinced the entire jury that it had to be it. And that is rather impressive. That is not what they are doing in Aalborg where
 500 they are saying "it has to be this one, so let's wrap it".
 AMDS: Yes, so you worked at the same time or parallel with Gabler and Cremer and tested models?
 NJ: No, we didn't work with them
 AMDS: No, not with them, but parallel, right?
 505 NJ: Yes...no, actually we were disengaged at that time
 AMDS: But not officially then?
 NJ: No because he didn't make a fuss about it
 AMDS: He just stopped sending anything as you said
 NJ: Yes
 510 AMDS: The testing of the models did that then not begin until....no, you did test his proposals...? NJ: We did test his. That [pointing to picture of scale model] was his design that was tested and that one is actually his last scheme.
 AMDS: Yes, this scheme is just before the halls as they are today, right? 515
 NJ: Yes because in the design he had there was modified with the curves and the model there is the one that the Australian architects inherited and were trying to convert into a mono-functional concert hall. You can see here [on the first model tested by Jordan ca. 1970] it is already a 520 concert hall only. Now it is no longer an opera hall but they wanted to try out his ceiling design to see if they could make it work. But we couldn't, we couldn't solve it and get a world class concert hall.
 So we had to abandon his design – it simply didn't work. 525
 AMDS: When talking about Utzon and the acoustics it is exactly the condition that the sound works as an instrument and reflects the sound towards the audience which is also the only absorbent – but that was actually the problem with the design? 530
 NJ: That was the problem. And that is the mistake, when an architect becomes so fascinated by his own idea that he doesn't listen to whether it will work or not but pushes it through. The Germans came to this design and they felt that it could...that it would work. If they had built it, it would 535 have been a catastrophe. Firstly the rise of the audience seats is much steeper – you need that when you're seeing opera.
 AMDS: Yes, to see the stage
 NJ: Yes. That means that your volume becomes extremely 540 limited, there is no reverberance in such a room. And the concert will suffer from it. And that is one of the reasons that one had to discard the whole idea of combining opera and concerts. It is not the right solution in contemporary Denmark... or a contemporary world, if you want quality. 545
 AMDS: But shouldn't the idea of the multi-functional hall have been discarded from the very beginning as your father said?
 NJ: Yes it should but they hadn't got the visions. They felt they it could be solved. Utzon thought it could be solved and 550 I think he still thinks so...that if only they had done as he had proposed it would have been great. So from that point of view it was a good thing that they didn't build it. That he has later gotten tail wind to his project is just as much caused by the inner design that the Australian architects 555 made wasn't as exciting, as creative, as Utzon could have done it.
 AMDS: It is primarily the architecture that they are critiqued for
 NJ: Especially the whole glass wall issue towards the open 560 and the inner design – well, that isn't Utzon. And I'll say that it is one of my fads that it was all right that he withdrew because he couldn't complete it because of the brief but when one has analysed it thoroughly and has concluded that the basic idea is wrong – it should be mono-functional 565 hall with concert and opera separately – then one damn well could have asked Utzon "do you want to participate again, with this new brief?". But one wouldn't do it, at that point the political relationship had gone so sour that one

570 wouldn't touch it. But that would have been the right way to go.
 AMDS: It was a tense political climate?
 NJ: Yes and they wouldn't go in that direction. And that is a pity. Because they could have gotten a subtle inner design – a design with Utzon's subtleness - instead of what became the result. And what they are doing now in the concert hall is, as far as I understand it, only these reflectors that they want to change a bit. There won't be changed anything and it will continue to be a concert hall.
 580 But the opera hall which is poor – that we can't deny. You can't put a large opera company in a hall with 1500 seats and that is almost the worst about Utzon's design when he positioned the halls next to each other. When the shells come down here, you haven't got any side stages. You can't do anything sideward at all. You can't get a ballet dancer to get up in speed and come in to the stage, right. There is no distance and that means that everything that takes place has to happen backwards and with the lifts up and down and that doesn't work in a modern opera production.
 590 I don't know whether you have been out to see the opera on Holmen [in Copenhagen]?
 AMDS: No, not yet. Well, yes from the outside but not inside.
 NJ: You'll be highly impressed by what side facilities they have there. Here there is none and there is nothing to do about it. What they have the ability to do is.....they want a larger orchestra grave. And that is something they have been looking into since we left Sydney in 1973 – whether it is possible to enlarge. And Arup's has been simply been struggling with that project and it'll cost a fortune to enlarge it.
 600 it.
 AMDS: Yes, it'll have an impact on the construction, right?
 NJ: It'll have an impact on the load-bearing construction, they simply can't take it. It would be cheaper to build a new opera house than to rebuild this one because it still only has 1500 seats – you can't change that, right. I have to admit that this project about rebuilding the opera – good luck!
 605 AMDS: Actually they'll attempt to increase the number of seats also.
 NJ: Yes, have a good time doing that. They can hardly tear up the floor and get many more seats. One might built a bit further towards the northern glass wall so that the balcony came a bit longer upwards. But there isn't any more room! Even the inner screen is completely black so that you can't see... there is no architecture in it but is actually glued directly to the shells. So if you get more seats you get less volume and then you'll get a worse acoustics – that is evident. That is one of the reasons that we used chairs with leather cover because we said "we are in the lower end [of the reverberation time and volume] so if there isn't sold out we'll get a little more."
 620 AMDS: You should have your fingers crossed that it isn't sold out!
 NJ: Yes. Even at that time it was attempted to get more seats and more volume but it....it doesn't exist. It isn't a fun assignment. I'm not sorry that I'm not on it. That is for sure. I would be willing to rework the reflectors and maybe the area around the podium in the concert hall because there I know that we have a strong tool and I know there is space. But that opera, I would rather say – forget it, build a new one. Then this one could be a more intimate opera and they could get a Grand Opera, maybe out on another peninsula or up in the Botanic garden or whatever. But it is a little meaningless to think that you can do magic tricks and that you can make something fundamentally different. It is not possible. That is what Jan Utzon has to take care of now as, as I understand it, his father's messenger boy. He goes to Mallorca and gets the designs and then out to the Australian architects who need to effectuate them. And what they are doing I think is quite all right, that they get Utzon reconnected, and everything that they are doing on the outside, the colonnade that they are doing, and I think they are also redoing the intimate theatre. The other facilities and the public area and so on I think are fine. But to touch the halls...that sure as hell isn't going to be easy, it certainly isn't.
 630
 635
 AMDS: But then the last part of the job where you were involved again, how did that take place then?
 NJ: Well the collaboration with the Australian architects was fine. They were extremely sympathetic and respected the rejection of that one [Utzon's last design]. It was some pill to swallow that the ceiling wasn't usable at all and when the design ends in something that doesn't look like Utzon's design at all... Utzon could have handled that better than the Australian Peter Hall but he wasn't allowed to. But anyhow; it became a concert hall that worked. That one [Utzon's design] would never have worked.
 640
 645
 AMDS: But they were well aware that this proposal [Utzon's] existed? Because some claimed that the Australian architects didn't even look at what Utzon had done.
 NJ: It wasn't available in such a detailing as it is shown here. But they were fully aware of it and you can see it here that the idea of the vaulted room that these curved, sectioned ceiling panels but they weren't in a level of detailing so that we could begin building it. Yes, sure it was tested but in a rather raw state and as a concert hall and it was discarded because we couldn't make it work. And what he, Philip Nobis, claims: that if it just been built the way it was it would have been fantastic, and then it would have been a huge success – that is a straight lie. Downright.
 650
 655
 AMDS: It is a glorification?
 NJ: It is a glorification of something that would never have worked. It is easy to claim today but thank god that they didn't build it! And if they do, then all the best!
 660
 665
 AMDS: I don't think that is the strategy that they have at the moment.
 NJ: No. When we came back home in the beginning of the eighties, we were still connected to the project because they had a project where they wanted to make the small opera below the small shells into a more drama theatre-like purpose. And we made a project for that which demonstrated that – and that was before we had Odeon – we could raise the direct sound so that you get higher
 670
 675
 680

speech clarity so that it could be used for drama. Then they
685 could vary between opera and drama. And it was actually
when my father was out there to present it that he drowned.
AMDS: Oh!
NJ: And then that game stopped. Then they stopped
changing it. It was in 82 that he died out there and since
690 then we haven't been in contact.
AMDS: Then it didn't continue?
NJ: No, then it didn't continue. Then came the nineties
with the revival of the Utzon connection when he became
honorary citizen in Sydney and gets the keys handed over.
695 And that is great. And I think it is great that he is involved
with charting the course of the future of the Opera House
AMDS: Yes he has written a design manual for that
NJ: Yes that is fine. They just need to be careful in
connection to the auditoria.
700 AMDS: Yes...hmm.... in connection to the work you did on
the acoustics it is my understanding that Utzon understood
sound rather poorly in the beginning – quite naturally in
the beginning – and that he actually misunderstood it. For
instance I can see in some of the old sketches that he was
705 working with a concave ceiling
NJ: Yes that was a pure focusing curvature, right. That one
he got turned around so he could see that it needed to
spread rather than focus.
AMDS: ...so he understood that
710 NJ: Yes, I think that appears from the last scheme that the
Germans participated in – he understood that it needed
to be reversed. Even though that was what he was most
fascinated by he respected that. But he maintained his idea
of this stepped rise and he actually had to due to the shells.
715 No, Utzon's understanding of acoustics was that if it suited
into his design it was all right, if it didn't then he didn't care,
then it was the acoustician who didn't understand anything.
And that is a lovely simple way to feel, right. Now the exact
opposite is happening in Aalborg, right. If it doesn't fit into
720 the acoustician's design, it is the architect that doesn't
understand anything. It is the opposite world.
AMDS: At some point I heard that Utzon perceived of sound
almost as light – can you confirm that?
NJ: Yes, you can almost see that from his shapes. He
725 thought that it was about projection but it isn't. Of course
you need a certain amount of sound and you will get it
because if you can see the orchestra, you'll get direct
sound that is evident. So if you get a clarity in the music
you'll get a picture of the early sound but you don't get the
730 reverberation as well if it is all projected. Then it is almost
like being showered in light.
AMDS: ...without any nuances...
NJ: ...without any nuances. And that was the mistake they
began by making. The first bad example was [Sal Pleiel] in
735 Paris where they thought it was obvious that the orchestra
should be sitting in the
focal point as a projector and radiate the sound towards the
audience.
AMDS: I don't know that hall
740 NJ: Oh, you don't know it? That hall you see repeated in the

Radio House Concert Hall. The principle is the same, right,
they sit there as the projector and radiates out sound, the
balconies follows the shape so everybody sits showered in
light and sound, you'd think. But that isn't the point.
AMDS: No, it is to activate the space 745
NJ: Yes, exactly. To get a audible picture of the room, of the
reverberation of the room of the room's contribution to the
music.
AMDS: It is incredible difficult, actually, to explain how the
hall should be designed because it is obvious that Utzon 750
worked with reflection lines and was inspired by the way
they were drawn and so on, so that he uses the dispersal of
the sound and begins to work with convex shapes. But from
that to understanding the basic principle...
NJ: Yes that is probably one of the greatest 755
misunderstandings ever made [shows the hall from the
competition with reflection lines indicated] to do something
like this. Reflection, angle of reflexion equals angle of angle
of incidence and then we'll have sound all over, right. He
could do that because his shells were floating down there 760
but it would never have worked.
AMDS: The manner you worked with acoustics at that
point was with these models in 1:10 and I actually though
they were history by now but recently at an acousticians'
meeting in Aalborg I heard acousticians argue that they still 765
have a relevance in connection to determining focus effect
and echoes. What is your take on that?
NJ: I'd say the greatest benefit the physical models can give
today is the pr value that they have – they do have charm.
To see picture of Denmark's Radio's new concert hall with 770
little Japanese people sitting on all the tiers and ...it is the
doll house game revitalized. And it is fascinating, it is neat.
But to be able to use is for anything you need to make a
design that is already almost 100% finished – you can't
keep changing the models. 775
AMDS: No, not when they are in 1:10!
NJ: Exactly. And you have to refine your measuring
technique in a manner where you empty the air out and
pour in nitrogen instead because else you can't move
up to ten times the normal frequency area. You have to 780
refine your microphone and a whole chain of measuring
techniques and regardless you'll never get to measure the
highest frequencies. And about being able to determine
focuses and so on – I don't think so. It is something that
would be picked up very quickly – at least with Odeon. 785
NJ: [Showing a project from Origen, Canada] This was a
design where there was a problem with echoes from a back
wall that curved on the floor and in the balconies. And we
could measure it when we were there to see what values
we were dealing with. Then we put all the drawings into 790
Odeon and tested it thoroughly – and tested the design we
came up with – and we can show that the echoes are gone,
they have been removed. And then I don't think there is any
point in building a model and showing it once more. The
only reason to build a model is to demonstrate how neat it'll 795
be with colours and light and the whole unity.
AMDS: ... it is much more the spatial feeling that it add?

NJ: Yes, that you are able to experience the model – this is how it is going to look in reality. I'd say that the acousticians who are working on Nouvel's concert hall in Copenhagen, they are forced to build a model because they are not using a decent detailing tool. They are using neither Catt nor Odeon. They are using an old-fashioned method that was developed during the eighties that we often call the tadpole method.

AMDS: What is that?

NJ: It is actually just a repetition of this [drawing of reflection lines] where you see how the reflections are and you plot them in where they are received at the audience as a dot with a line – this is where it is coming from and this is where it is ending. And then you can see the distribution of your tadpoles – whether they are equally distributed or a clustered. But that is all you can see, you can't measure anything. You can't measure early reverberation time or clarity or lateral reflections. You can only visualise your tadpoles. And clearly when you have such a primitive tool for detailing, then you have to build a model in 1:10 because otherwise you'll be in trouble afterwards, then nobody will believe you, right? And I think it is astonishing that the Japanese hasn't gotten any further. It is amazing that they have stagnated when you know that detailing tools that are so great are available. I mean, with Odeon you can auralise, with Catt likewise, and you can do it simultaneously: you can change a reflector and simultaneously hear how it'll sound.

AMDS: But is there any reason why they are so....

NJ:conservative? Yeah, it is kind of Russel Johnson and Artec again, right. They have a vision about how a concert hall should be solved and they have made some good concert halls, no doubt about it, but they are not attempting to document the quality beside the model. And that means, in my view, that they are very limited in their freedom of detailing. For instance if the architect brings some very new ideas to the table they need to take a stand to them based on some tadpoles! Cause they can't keep doing new models.

AMDS: Yes, it is not a very flexible tool

NJ: Not at all. But today we can take the cad drawings of the architect – which are very substantial and showing everything – and import them directly into Odeon. You can't do that with Catt.

AMDS: Yes, well no, not directly. It has to go through another step, but almost!

NJ: But that is one of the places where Odeon is clearly better than Catt.

AMDS: Also in connection to reflectors. I was working with reflectors and they had to be compiled from triangles, of course, and that meant that I got around 300 small files which I had to sit and edit for materials and absorption coefficients.

NJ: Yes, that is hopeless. You haven't started on Odeon yet?

AMDS: No

NJ: There is a education edition that is not very expensive

AMDS: Ok. Yes, it is very exiting when the tool enables one to hear an un-built room. It is very fascinating.

NJ: Yes and one can find out "how does it sound if I turn this wall". I mean, you don't even have to measure the results. Us as engineers like that, measurements with reverberance and our criteria. But the ones who've got ears to listen might as well use them.

AMDS: Sure. I also think one of the advantages of this simulation programme is that you can start working with more subjective parameters than before. For instance the reverberation time is used a lot and still is but Catt and Odeon can get us a step further in using some of the parameters that are difficult to measure but is closer to the actual experience in the room.

NJ: Yes, but then you've got to have a normalised ear, right. You need a consensus about what sounds good I think it is easier to agree on whether a room is beautiful, or whether it is bright or the colour is right or something like that but whether it sounds good...

AMDS: Then you'd need to do various tests with different types of spaces

NJ: That is actually what one is doing with AB loudspeakers, right. It is fairly simple. In Germany, there they are thorough, they've had a symphonic orchestra on tour to 10-15 chosen concert halls with a test audience and then the other audience that comes to these concerts and then played in it and evaluated afterwards which concert hall gets the best rating and how we classify them in comparison to each other. That is one way to do it. Another is to record in various listening positions in the concert hall.

AMDS: But then you are again limited by equipment

NJ: Yes but it is the same equipment and the same chosen seats. On the floor, to the side... and here it has been evident that nothing has beaten the shoe-box-shape. Not even the Philharmonie in Berlin gets first class rating. But that is what they are building in Copenhagen today.

AMDS: But it has other qualities as well.

NJ: Clearly it has other qualities that Denmark's Radio values. They don't care much for the musicians because they want it to look spectacular when it is shown in television. It needs to look good, there you can't have the shoe-box-shape – how the hell do you make that exiting? How do you do Russel Johnson in Aalborg exciting?

AMDS: Beats me.

NJ: And that's why they didn't want the shoe-box-shape – it said so in the competition brief.

AMDS: But there are so many parties, who should one satisfy?

NJ: I think that when you build a concert hall and want it to be in the world class elite it is primarily the music that needs to be promoted over the visual or visionary. Of course a beautiful concert hall can enhance the audible experience a little but it is primarily the music.

AMDS: Well it is the working place of the musicians and they are going to be there the most

NJ: Yes, and there it is known from Berlin that they have problems. You can suppress that in Germany because you have a von Karajan or a similar guru but I don't think you

can do that in Denmark. But let's see – or hear.
 AMDS: You say that you think you've gotten involved
 earlier in the process now compared to earlier. That you've
 915 participated on competition projects. Is that a tendency
 over all or is it only in connection to your relationship to
 some architects?
 NJ: I'll say that when it comes to schools, dwellings and
 institutions and stuff like that, the acoustician is not
 920 introduced before it has been settled how to build. When it
 comes to churches, cinemas, concert halls, multi-purpose
 halls a greater attention towards bringing the acoustician
 in earlier – when the first lines have been drawn – is
 prevailing. And in connection to competitions there is
 925 also a growing understanding that there needs to be an
 acoustician attached. What is the problem in connection to
 competitions is that the architects think it is expensive but I
 don't charge for that.

Interviewee: Norman Gillespie, CEO of the Sydney Opera
 House
 Interviewer: Anne Marie Due Schmidt
 Date: May 5 2005
 Location: Norman Gillespie's office at Sydney Opera
 House
 Notes:

AM: where is the project of the Opera Theatre – I mean with
 the funding for it? I can stop the tape recorder if you'd like... 10
 NG: ...I am very satisfied that the designs are complete to a
 very high degree and that the costings are robust and that
 everything is 'buildable'. It is all doable because it looked
 impossible to do that quality of theatre inside the shell but 15
 that has all been solved, so that's doable...
 The money has gone up considerably in today's money it's
 about 600 million dollars and every year we postpone it's
 another 30 or 40 due to inflation so... if the work couldn't
 start until 2008 you'd be up to around 800. It's a big 20
 amount of money. In today's climate... you know, nobody is
 going to write you out a check, that's the reality. We don't
 have big philanthropies in Australia like they have in the
 US, so when they are refurbishing the Modern Art to 500
 million US dollars all that comes from private funds. In 25
 Copenhagen all that is provided by one person! With great
 tax-advantages to him of course.
 Here we have got neither big Government checks nor
 philanthropies so we try to be quite innovative and say 'well
 there are other ways of raising funds' and it'll probably be 30
 from the public through a bond scheme, a premium bond
 scheme, we've got them in the UK, where people buy - at
 a Treasury Bond facilities or in the post office - you buy an
 interest-bearing bond and you get to be a part of the draw
 that happens every month. 35
 AM: So is it like a lottery then?
 NG: It is and it isn't because you have actually a piece of
 paperwork that says 'my hundred dollars is safe' and I can
 get my hundred dollars back whenever I want. It is like a
 perpetual lottery. But if you are going for fifty years and 40
 they have for 25 billions of worth of prices. People just buy
 these, they put them in a drawer and if they get lucky they
 have won a price. And there are lots of prices there is a
 one million price at the moment so on average should get
 a return on ...quite enough. What we are suggesting is to 45
 use that in Australia. It has not been tried tested but we
 think it may well work. And then... so to do that, though,
 we've got to get the tax redemption and the Commonwealth
 Government's permission that the prices that you win are
 tax-free. If you can't get that it doesn't work. So at the 50
 moment we are actually - because it is at state level you'd
 have to get the permission to get the pole of the federal
 government here – because they conduct the tax policy – to
 start negotiations on whether it is possible or not to get the
 tax redemption. So that's where we are at the moment. 55
 AM: Ok
 NG: If you can't get tax free there is no point in going any

further.
 AM: No, ok.
 60 NG: Ehm... it is scary because there really isn't an alternative. You can not patch up the old thing, you oughtn't to patch it. So it's tricky. Of the public reception you'd think it would be simple, it's a national icon, it's a popular building so why wouldn't you but the fact that it is an opera
 65 theatre that you are building...the vast majority of the population is never going to be inside the opera theatre. One: they couldn't afford the tickets, two: they don't like opera. So not quite like in a European city where you would expect to have a good quality opera, 'we could do without'
 70 AM: Yeah, 'we could do with a sports stadium instead'
 NG: Yeah. So I'm really more selling it from the point of view of a national icon and tourism rather than the opera theatre because the building attracts millions of visitors and hundreds of millions of dollars every year.
 75 AM: Yeah. I don't remember whether it was you or it was Joe Skrzynski who said in an interview that for tourists it was one of the primary attractions to come to Sydney from the outside but when they had been inside it was dropped to like fourth or so.
 80 NG: Correct.
 AM: It's quite scary
 NG: Well it is because people won't come back. And word of mouth will go 'ah, it's not all that good'. And it all goes back to that, you know, frightful mid-60ties when Utzon didn't get
 85 to finish his work - simply the victim of the politics of that time, that's what he was. Inevitably we reconnected and he has made some bold design - the Utzon room and the loggia - and now the Opera Theatre. So when at some point we've pursued the politicians, we know how to do it and that's important. Clearly it is going to come [...]; it is such an economic generator...
 AM: yeah and such an important building for Sydney and Australia as a whole.
 NG: The trouble is that Jorn built the outside so well that it
 95 looks fine. Look at it from the outside and you'll say 'why do you need to spend any money on it?'
 [laughter]
 AM: Yeah, you can't see it being shabby on the inside
 NG: But you know, we'll keep trying and trying. You need a
 100 champion, who is going to say 'I know, I hear you, but we are going to do it' and that needs to be the prime minister or the treasurer.
 AM: But you have a good support in Bob Carr
 NG: Oh yeah, but he hasn't got any money.
 105 AM: No.
 NG: Oh, yeah a great support. His allowances have allowed us to come so far, but ehm... this is too big for him.

Interviewee: Greg McTaggart, Project Director, SOH Building Development

Interviewer: Anne Marie Due Schmidt

Date: March 22 2005

Location: Greg McTaggart's office at Sydney Opera House Building Development

Notes:

AMDS: I should start by introducing my project. It is a PhD that I am doing for the University of Aalborg in Denmark. And one of my case studies is then the reworking of the Opera House and that is why I am trying to get an understanding of the background of the project.

GM: Ok, can I show you these [a pile of reports lying on the table]?

AMDS: Yes of course

GM: Ok, let's start from the beginning and put these into order. Back in sort of the late 90ties, the Opera House started looking at the building itself which hadn't been touched to a great extent since Utzon left it in the sixties and the building was finished by a team of Australian architects. So they developed a Strategic Building Plan which was published in December 2001 but they had been working on it for quite a while so this is really a wish list of projects that could possibly be done to the Opera House to take account of what had happened in the intervening years from when the building was opened and how it was currently been operated and take account of some of the changes that had been made to the design functions after Utzon had left. I don't know how much you know about the history..?

AMDS: Yes, I know how much it changed since Utzon left.

GM: So originally the big hall, the major hall was going to be an Opera Theatre and a Symphony Music hall and the little one was going to be a Drama Theatre and for small operas, then the change of government in the mid-sixties, they changed the brief to just put symphonies in the big hall and operas into the smaller hall, so it is really shoehorned in there. It is a very compromised design. The other thing that has happened is, over the years there were developed the three theatres on the western side, which was never really a part of Utzon's plan. I think there was an experimental theatre and some rehearsal rooms down there so his original concept did not allow for these public theatres on that side. I think his concept was that the pink area [podium] there was all back-of-house space and the blue [over the podium] would be the performance spaces. Now it has got these three performance spaces squeezed into what was going to be back-of-house area. So this [Strategic Building Plan] was taking all that into account and developed a proposal for different projects which were estimated at a cost of a billion dollars. None of which was funded. But at least it was a starting point so picking up all of these things that needed to be addressed. Adapting for the future, picking up some of the historical changes that had happened over the years.

| | | | |
|-----|---|-----|--|
| | AMDS: And the author of this one, is that the Sydney Opera House Trust? | | |
| 60 | GM: Yes | | |
| | AMDS: In collaboration with? | | |
| | GM: The local architects, Johnson, Pilton, Walker had something put into it | | |
| | AMDS: Ok | | |
| 65 | GM: One of the fellows here at my office [John Deere] was involved in putting it together and another guy who sat over there [Johman Winney]. So out of that and in 97 they engaged Richard Johnson who is with a firm Johnson, Pilton, Walker - previously Denton, Corker, Marshall - he | | |
| 70 | came on board to become the Opera House's architect and the chairman Joseph Skrzynski, who I think you know, he gave you the introduction | | |
| | AMDS: yes | | |
| | GM: he started talking or toying with the idea to reengaging | | |
| 75 | Utzon to get involved with some of these projects. So between Richard and Joe they managed to do that, they got Jorn Utzon involved again. And one of the first things they did was to get him to look through this [strategic Building Plan] to look at some of the projects that could form the | | |
| 80 | base of this venue improvement program. The other things they asked him to do was to put down in writing all of his design principles which was quite an important document, a break-through actually, to have documented in one place all of his ideas so that any future projects could be guided | | |
| 85 | by those principles. So coming out of... peeking through those... working through the Utzon Design Principles they came up with The Venue Improvement Plan, the other document that is also important is this Conservation and Management Plan. This is third edition, so the first and | | |
| 90 | second edition was written without taking into account any of Utzon's input so the one now takes into account the Utzon Design Principles. | | |
| | AMDS: Ok | | |
| | GM: So the principles is now embodied in this report and | | |
| 95 | what this does is that it establishes all of the principles for conserving the Opera House. It also looks at each of the areas and assigns levels of significance to each of the items, so A is the highest level of importance, D is the lowest. Intrusive means something that has been added | | |
| 100 | over the years but should be gotten rid of. So this is sort of a bible for us whenever we are working on one of our projects. It is quite important. | | |
| | AMDS: could it be true that I found this one in an earlier edition at the library? | | |
| 105 | GM: You may have | | |
| | AMDS: By Kerr, something | | |
| | GM: James Semple Kerr, you would probably have seen one of his earlier editions, yes. That is a public document so if that would be of any use I could probably find a copy of that | | |
| 110 | AMDS: Yes, that would be great | | |
| | GM: So that was a little of the background. Then we get to the Venue Improvement Plan, so the Government said 'well, we obviously can't afford a billion dollars but if we give you a little bit of money what projects would you select?' So | | |
| | between Richard Johnson, the Trust and Jorn Utzon they came up with the six projects which added up to around 70 million dollars, Australian, in 2002 so those six projects are [flipping through the report] the Opera Theatre, there were two parts of that – one part was to update the interiors to the Utzon design, to add the colours that he originally envisaged – these are some of his earlier sixties designs – but really all the money allowed for was really a bit of paint, there wasn't a great deal involved in that. The second part of that was to increase the design of our orchestra pit. The current pit, the shaded area is all under the stage so they have very cramped and noisy conditions. The idea was that we'd take two rows of seats and expand the pit into the auditorium to give them a more open pit. There is a major structural element that runs around there and ties the legs of the shells together, so that was a very expensive project for really not a lot of return. All it did was really to improve the pit and it possibly could have compromised the acoustics in that auditorium. At the moment there is a balance between the music and the singing with the singing is heard more loudly in the auditorium and the music is restricted because of this narrow neck of the pit. Excuse me for a moment | 115 | |
| | [a co-worker comes in and they have a brief conversation] | | |
| | GM: If we open the pit up, what could happen is that the music become more loud and the singing wouldn't be as loud as that and it wouldn't have that same balance so in January 2003, Arup Acoustic, who is engaged as our acoustic engineer for this project, published a benchmarking report in which they looked at ten key criteria for acoustics and measured the Opera House's performance against ten or twelve other important theatres around the world. And what came back was that except for this clarity of the singing from the stage and the intimacy of the audience with the stage it came last in everything else. | 120 | |
| | AMDS: Ok! | 125 | |
| | GM: And the only thing really to fix that was to look at something bigger than what was proposed in those two projects. I'll get back to that in a minute, so just going back through the other projects: the other one was the forecourt, so as you walk down to the Opera House there is a big expanse of granite paved area. The idea was to turn that into a sixth performance venue, so the two big theatres and three western theatres and the forecourt would become the sixth one. And they looked at bringing in temporary seating and temporary fencing, temporary stages and all that sort of thing and ran ticket sale from the forecourt. In late 2002 they ran a season of that and they got a lot of criticism from the neighbours and from the architectural fraternities who thought it wasn't fitting for the opera house, it contravened some of the principles like having the grand vista to the Opera Hall across the forecourt so that project has been put on hold for the moment. But what we'll probably do is put in some basic infrastructure like services for data and communication and power and that sort of thing to have those sort of performances where people just sit on the monumental steps look at a temporary stage, but it'll only | 130 | |
| | | 135 | |
| | | 140 | |
| | | 145 | |
| | | 150 | |
| | | 155 | |
| | | 160 | |
| | | 165 | |
| | | 170 | |

| | | | |
|-----|---|-----|--|
| | be there for two or three days rather than a whole season of different events. | | |
| | AMDS: ok, so that was a whole season the last time | | |
| 175 | GM: Yes, they ran five or six events that ran over that two months, so if you imagine that whole forecourt was covered in temporary fences, tents for back-of-house, stages, temporary seating | | |
| | AMDS: and all of the sudden it is not all that temporary | | |
| 180 | GM: that's right and it detracted from the experience for people visisting the Opera House. So we'll still be doing something in the forecourt but it won't be to the same extent as was originally anticipated. The next project was the concert hall - a very limited amount of money was given | | |
| 185 | to us to look at acoustic studies and modelling. And try and do some basic improvements to the acoustics. that hasn't been that easy because we are finding that the amount of money we've been given can't really buy anything worthwhile so we've done the same acoustic benchmarking | | |
| 190 | study that we did for the Opera Theatre, so looked at the concert hall compared to others around Australia and around the world. | | |
| | AMDS: And how did it come back? | | |
| | GM: it rated good on some criteria but generally quite | | |
| 195 | appalling in some others. | | |
| | AMDS: ok | | |
| | GM: The concert hall is different from the Opera Hall in that the interior of it...I think even Utzon himself thinks that it is not too bad and really one wouldn't want to change | | |
| 200 | the interior of it so we looked at doing some changes to the stage: the type of timber on the floor of the stage is important for transmitting especially the low frequency sound. We looked at possibly hanging a big reflector of the ceiling to bounce some of the sound back down to | | |
| 205 | the musicians and out to the audience. We looked at the shape of the stage around, at the moment it does that, it leans out so instead of keeping the sound in it all disperses very quickly. There is other minor stuff like looking at air-conditioning plant which is creating background noise | | |
| 210 | and other little cracks and things that are in the place where noise escapes. And the conclusion of it all is that the only thing we can possibly do is looking at some improvements to the stage, possibly combining some of our capital funding with some of the maintenance funding | | |
| 215 | that we'll need over the years for re-servicing the stage, reconditioning some of the mechanical equipment for the risers of the stage we could be able to get something that is useful and just coincidentally our...the new conductor for the Sydney Symphony, an Italian guy called [Jean Louis | | |
| 220 | Giometti] he has this idea of reconfiguring the how the musicians sit on the stage from this sort of quite a random pattern to semicircular horseshoe-shaped with tier-rises to get some more organisation in and structure into how the musicians are laid out. Our acousticians think with the | | |
| 225 | right timber there can be some improvement mainly from the transmission from the noise into the timber because they are tiered up we get some sound coming out to the audience better and by getting the musicians in a more | | |
| | logical relationship to each other will solve some of their communication problems. What happens at the moment is | 230 | |
| | that because the ceiling is about 25 meters high the sound goes straight up and by the time it reflects and start coming back down | | |
| | AMDS: yeah, they can't hear themselves. | | |
| | GM: they can't keep up with the other players. I did have on my desk here a book from ...is it Los Angeles...ah, here it is. | 235 | |
| | This one [an auditorium by Gehry] is done in Los Angeles with a similar setup with the risers if you've got time I'll try to find some pictures of what it is going to look like. And we've actually made a 1:50 model of our stage with the | 240 | |
| | risers on so we can show the conductor what it is going to look like and you can play around with it and get a feel for how it all works. So with that one we haven't actually build anything yet but we are still working on the investigations. | | |
| | AMDS: but there are some acousticians appointed to this one | 245 | |
| | GM: yes, Negata from Tokyo and Arups are the ones for the Opera Theatre. Another project we have is the western foyers, so coming out of the Strategic Building Plan | | |
| | AMDS: yes, because you had those three venues | 250 | |
| | GM: yes, we had the three venues in there and we have a solid wall on this side basically. Utzon has two competing design principles on that one. One of the principles said that the podium should be solid and look like the massive outcrop that he imagined when he first designed the Opera | 255 | |
| | House and the second is that people going to performances in the Opera House should have a sense of orientation and be connected with the harbour at all times. So get the connection with the harbour he proposed to make some openings in the podium then by doing that it contravenes | 260 | |
| | with his other principles of having the solid thing, so he came up with the idea of having a loggia or a colonnade to disguise the openings and that came up with this project [showing a computer rendering done by Richard Johnson's office, the one that is repeatedly published] creating new | 265 | |
| | openings through the walls and then disguising the view creating this loggia on the outside. So when people view it from the outside, that shadows over the openings so for this one we have started the work, we have got all the designs done. We put the foundation in for the twenty columns | 270 | |
| | for the loggia - that went in before Christmas and we've just awarded the contract for the loggia and the openings themselves. And they contracted should start on site right after our Easter holidays next week. So that is well under way. I'll show you, we've got some photographs of it, before | 275 | |
| | you leave. The last one in the Venue Improvement Plan was the Reception Hall which is a little function room. That is what it looked like before and this is what it looks like now. That project is finished it has been operational for about six months. You can have a glance through that [photographs | 280 | |
| | of the Utzon room] | | |
| | AMDS: Is there some of the old room as well? | | |
| | GM: I don't have a lot of good ones of the old room, it was guttered before I began on the project. | | |
| | AMDS: ok | 285 | |

GM: but you can get a feel from that. This was green carpet, this was old timber panelling. These are the folded beams which were restored and put the special lighting in. just showing the tapestry that has been designed by Utzon.

290 AMDS: yes with inspiration from a music piece
GM: yes. Have you been in there?
AMDS: yes I have seen this room
GM: I'll just get the other ones while you look at those.
AMDS: You even have Danish chairs in it

295 GM: we do, Utzon selected those. The Fritz Hansen chair was another alternative but we went with that because that was his first preference and they went for a good price as well, they were cheaper than the Fritz Hansen ones.
AMDS: Yeah, the Fritz Hansen ones are very expensive.

300 GM: that is a computer generated image
AMDS: ok, of the new loggia
GM: so we have nine holes happening, there's six windows and three doors and here you can see how it is blending in a disguising the openings. So these are all pre-cast elements, all of the window-niches are all precast. We've

305 actually build a prototype of one of these bays and of the door niche. Jan Utzon was here for a month and went back last week, he came and viewed those and approved them and we made some changes to the design after looking at the prototypes.

310 AMDS: It is very helpful
GM: yes and that is Utzon's way of working apparently. By prototyping and working with the manufacturer. We are trying to continue that where we can. So that is the new Venue Improvement Plan for the loggia. What we also did

315 was ask Utzon to come up with a design for the interiors so the floor, the ceiling, these walls [of the foyer east of the loggia] which is all part of an interior project which we haven't got any funding for but we thought that we'll get his ideas down on paper.

320 AMDS: So you have something to work on or something to get funding by.
GM: That is right. And with the system that we have in NSW, the planning, we actually have to get development

325 approval for the interiors as well, so one day in the next few years we get approval and the money then we can just get straight into doing the project. That is another view. So we are doing those doors and windows but none of the ceilings or anything are part of the current project. This [one of the renderings] gives you a feel for the view out through the niches.

330 AMDS: Oh, these are the entrances or not [you go straight towards the wall into a glassbox and turn to either side to get in]
GM: They are the entrances and there is a door on that side and a door on that side. They are actually a bit bigger than that. When we did the prototype you get a better feel for the size of it so we mocked up that whole section there including the niche-part, very useful.

335 AMDS: I went to see the lobby or what we should call it now, it is really bad
GM: It needs a lift!

340

AMDS: Yes!

GM: So they are our approved projects so what we're doing as we come to each of these, we obviously have a bit more time to think about it and think more deeply so out of this western loggia project....this one [the Utzon room] was only for the room it self when we started doing the design work but we thought what is this room going to be used for and it is used for entertaining and pre- and post-show functions for the Opera and the Ballet, for corporate dinners and things like that. The kitchen that services it is right down the northern end under the Opera Theatre, at the front and when they brought food to the old hall they'd bring it up a lift back-of-house, across the great foyer and then down the stairs into the room – which also didn't make a lot of sense, so what we ended up doing was we demolished all this and we put a goods-lift in the corner downstairs and we build a new kitchen directly underneath. So as well as doing the room we got much better catering facilities, so each one of these [the Venue Improvement projects] are developed and improved as we go further into the project. So in the loggia we went a step further into the interior concept design we're still working to get some approval from the Government, trying to get some money to build it. Then the big one is the Opera Theatre ehm...what we're doing now is this project to do the auditorium...the bit of paint on the walls and the bigger pit didn't really stack up as a really solid business case to spend 40-50 million dollars and all you get is a coat of paint and a bigger pit, so we've then been looking at the bigger picture and we had approval to do some concept design work. So Richard Johnson has been working with Jan and Jorn Utzon just to say that if we had unlimited money to make this Opera Theatre the best it could be, how would we do it?

345 350 355 360 365 370 375

AMDS: Yes
GM: And the key to the whole thing really came out of some of the acoustic modelling...we've something like 1500 seats in here at the moment but only about 1300 or so that gets sold regularly. In acoustics there is a rule of thumb that you have so many cubic metres of air per seat to get the right reverberation time and everything else they want to really have the right number for opera and ballet we want about 1650 seat but as soon as we put this rule of thumb onto this 1650 seats we needed 11000m3 or so of volume. This hall only has 7000, so how do we get the extra volume. Also we can't go up because the shells are constraining it. The only way is to go down. So the proposal is actually to demolish the whole stage, the pit and the auditorium and lowering the whole thing down four and a half metres so that's where this design has come from. In achieving that volume it also does other things, it addresses some of the sightline-problems that this theatre has currently got, addresses some of the big problems that the stage area is very small against international benchmarks such as Tokyo, Covent Garden, the new Copenhagen Theatre are something like 6 or 8 or 9 times the area that our stage has got.

380 385 390 395

AMDS: Ok, so the actual stage or ..

400 GM: the stage and the wing space
 AMDS: ok
 GM: so because the shells are coming down, doing that [enclosing the stage] and because it has been shoehorned into the smaller hall it is really not adequate for major
 405 operas or ballets so by sinking it down and getting it down below where it also gets wider, we can pick up about 60% extra stage area. We can get all the dressing rooms at the same level as the stage, we can get four entry points, one in each corner to get people on and of the stage where at
 410 the moment they have to line up to get through one entry and they are all back through the corridors to get onto the stage. So it is not really that good for a modern day theatre. So this project is still reasonably confidential, I can show you what we've been working on. So this is in a hall that
 415 has been sunk down the four and a half metres and has the 1650 seats roughly and it gets back to Utzon's design which is based on a projection of cylinders. It has now been through five or six iterations with the acoustic engineer and they've now gotten to the point where Utzon is happy
 420 with the shape and the acoustic engineers are happy with the reflections and all of the other acoustic criteria. We pick up the extra 60 % area on the stage and we've got a higher and wider proscenium arch, we've got about an extra 4 metres of flying height for the scenery, so there is
 425 a lot of benefits that has come out of that. But it costs a lot of money which we don't have at the moment. To get you a feel for it [showing renderings of the hall], Utzon has been playing with different colours, the gold and burgundy colours. In some of the later schemes he introduced orange
 430 which was about the lightest, that was around February. I think he has been through another two colour-schemes since then.
 AMDS: Yeah
 GM: The seats have been green...he has looked at different
 435 balconies, the sloping ones, the stepped ones. The stepped ones, he thinks are the right ones, that's the current thinking. More of the same, just to get you a feel for it. At the moment we've only got stalls and one secondary level but by dropping the floor we can pick up another extra
 440 upper tier, it helps us with our seating numbers. Ehm...all pretty well in sightlines and acoustics. We pick up an extra level of foyer at the northern side
 AMDS: Oh, yes, with the two tiers that's better.
 GM: Yep and we get better access for people with
 445 impairments. At the moment all we've got is a route that goes back-of-house and brings them up to the front rows to there is two positions on either side for people in wheelchairs
 AMDS: you can't have too many of them, huh
 450 GM: that's right. What we'd be doing if we get the money to do this scheme is to put in front of house escalators and lifts to bring people with impairments up here. We'd have about eight positions in here and another eight seats in this mid-tier level. So there'd be much better access for the
 455 disabled. That's a view from the seating, looking straight up the ceiling to get a feel for the colours so he's going

from bright colours in the back to the more subdued in the front. So people's eyes are not drawn away from the stage. This is a section through there so you can see the stalls, the middle tier and the upper tier, see the various levels of
 460 foyers in here.
 AMDS: is this the current level or?
 GM: no this is a new level, this is all at the new level. You can see it is one, two, three, four; we'll end up with four levels of foyer. We are putting in lifts that'll connect back to
 465 ground level and some function rooms in the front so the idea will be to try and get some common hospitality working before and between shows for the presenters. So a view towards the back of the hall [a section through the hall on the shortest side]
 470 AMDS: You can see the relationship between the shells and the theatre.
 GM: They worked really hard to squeeze as much as they could to get all the volume. There has been a lot of work with the acousticians to stop external sound from getting into the auditorium. We did some tests where we one
 475 Saturday morning got big speakers, putting out 130-150 dB and blasted sound out on the outside and measured sound on various points on the inside to see how much noise was transmitted through the shells to work out how much we
 480 needed to take out with the new ceiling. Mainly to try to cut down costs because that's very expensive.
 AMDS: Ok
 GM: And also to get some thickness out of it so we could get more volume. The other thing we did was at the
 485 moment there is an airconditioning plant up here above the stage, the air drops down from above onto the patrons. That is not a very efficient way of be cooling people and it is also very noisy and the noise gets into the theatre so part of this design was to put the plant room down here to push the air
 490 up between the seats.
 AMDS: Yeah, that's much better
 GM: Just a small plant-room remains – mainly for smoke extraction. If you get a fire you need to be able to get the smoke out. So that'll hopefully cure some of the acoustic
 495 issues as well. These are different sections through the theatre where you can see how it is getting narrower as we are getting back into the constricted part of the shell. And some details of the boxes. These ones are probably about
 500 the ideal sightlines, we looked at another option where we were turning the seats around so you would sit side by side as when you're sitting in a bus. We loose a few seating numbers but we'll get better sightlines. By dropping the floor down we are going to get access from the southern foyer here through on the level to the northern foyer. At the
 505 moment we have a lot of steps to go up so it's a big benefit for getting people in wheelchairs through so we'd have a lift when we come from our carpark level or our vehicle drop-of level up to the box-office over here. Then through the box office and then up a special escalator here where
 510 the threads will lock so you can load a wheelchair on. And people can walk through or straight into their seats in here or get into another lift to get into the mid-tier level. So

there's a big improvement. A lot of extra toilets, the opera house suffers a lot from a lack of toilet numbers, there is always big queues before a show and in the interval. We've got around 50% more around the box office, mainly in the ladies but that is still a problem so we are looking in to get another 50% up these northern areas. They [the plans we are looking at] are just going up to the upper levels. My purpose for doing these are actually to get our costings right and make sure we can actually build it.

AMDS: Yes

GM: We've satisfied ourselves now that we can build it and we are pretty happy with our estimates that they are realistic and the matter now is the Trust lobbying with the Government to see if we can get approval to build this. But it might be some time in the future.

AMDS: Yes

GM: But it is good to do though, Jorn Utzon is nearly 87 so...

AMDS: Yes, it is good to get it done now

GM: Yes, at least we've got his ideas captured. That's the corridor where you see up the steps. That dark patch there is the level ramp that goes through. A lot of this project has been done on TriForma. It is a 3-d cad program, so when we started on this VIP [Venue Improvement Plan] project, a combination of going through the old drawings and have a surveyor in there to pick up points, we developed the model for the auditorium. Now that we've started looking at this bigger project it has been extended through to the stage area, some of the back-of-house and through on to some of the approach areas. So this is just an idea that is sort of drawing you can get out of Triforma. But all of these drawings have been generated out of that program.

AMDS: Is this the stage tower?

GM: yes. A lot of steel in there. And you can see how cramped it is under the shapes, conforming to the shape of the shells [the stage tower ends in a point that fits up under the highest point of the 'shell']. The same happens from front to back, so the width of our hanging bars for the scenery gets very narrow at the back when you are under that point of the shell. The guys down there that work on the scenery do a good job with the limited space they have.

AMDS: yes

GM: I found this book just to show you the concert hall. So this is the Walt Disney in LA which is just recently opened.

AMDS: Oh, the Frank Gehry one

GM: Yes. That's the sort of idea we are looking at for the stage. So instead of being on a flat platform, the musicians will be on risers and spread around in that horseshoe-shape.

AMDS: Ok

GM: So at the moment we've build the model for the maestro to look at and we're just doing some cost estimates for different short-term, temporary, moving/ temporary into permanent to see what the cost is and how we go about doing it.

AMDS: Has he tried such a configuration before, the director who is there now?

GM: He knows of it, I don't know whether he has actually conducted in it, though. He has seen it around Europe and it's very popular in Japan apparently this sort of configuration. That is why Negata and the new maestro had the same idea.

AMDS: Ok!

GM: We had a meeting back in November 2003 ...well it was hard because the maestro doesn't speak a lot of English and Nagata doesn't speak a lot of English, so an Italian and a Japanese... but they managed to get their point across

AMDS: they looked at the picture and nodded [laughter]

GM: yes! So that's the history of where we are and how we got there. Does that cover most of what you wanted to find out?

AMDS: Yes that was very helpful. Let's see ...perhaps if you would explain me a bit more about the general concept of the Sydney Opera House Trust. Who actually funds your work and how big is it?

GM: The Opera House Trust has 10 people in it.

AMDS: Oh, it's that small.

GM: Yes, they're eminent people from the community, they've been appointed by the Government to sit on the Trust, they term for three years and they can sit up to three consecutive terms so a total of nine years. And Joseph Skrzynski has just finished his nine-year term. We've got a new chamber-man just starting now. So they are people from all different types of expertise, people from the arts community, people from the finance area. We have one Trust member right now who is very experienced in Government projects, so he has been brought on because of this building project to give his expertise. We have some indigenous representatives... So they have a good mix of different types of people so they can all input into the different types of problems that come up in the Opera House. So that body meets once every two months and they are run as an executive group so we have a director of finance, a director of operation and maintenance. I don't sit on the executive but I report directly to the CEO and look after all the major building works. We have performing arts personnel and customer relations – that'll be the main areas. It is fairly diverse range of activities they do. The executive and the Trust are then responsible back to an organisation that is called the Ministry of Arts- that is a Government department. They have a Director General who also happens to be the Secretary of the Cabinet and the minister who looks after the Ministry of Arts just also happens to be the Premier, Bob Carr. So we have, I suppose, a good political connection, having the premier as our minister is useful.

AMDS: Yes I would imagine!

GM: But that might be different after the new Government comes in, but that's how it has been for the last eight or nine years.

AMDS: Ok

GM: Then under the executive there is the various staff that do the day to day running of the building.

AMDS: And they report back to you? Or?

GM: I'll just print of an organisational chart...[printing]... this'll make it a bit easier for you.

630 AMDS: Yes
GM: The top is the Ministry of the Arts and the Government, the Trust reports back to them, then there is the executive venue - the executive team – beneath the Trust, so the different portfolios that I mentioned before. Then that's

635 my group up here, reporting directly to the CEO and we've got a security group that reports directly there because, I suppose with the current climate for terrorism, the Opera House is taking security fairly seriously.
AMDS: Yes, it would be a good target.

640 GM: So they've established this separate security team and they are putting a lot of extra infrastructure and they've beefed up the number of people on site, that sort of thing. Under me, so this floor here is really all my team, I have only a handful of permanent staff but we've employed a

645 private sector project manager to manage the design and the construction just of the Venue Improvement Projects. We manage some of the other projects ourselves. We've got our permanent people supplemented by private sector people because...when the VIP projects are finished we

650 don't get any new big projects and we don't need as many people so it's easier to manage the resources by doing it that way.
AMDS: Ok. So it is actually this, your group, that's actually quite big now because of all these projects.

655 GM: Yes, we've got a lot happening at the moment. I don't know whether you met Norman Gillespie, the Chief executive?
AMDS: No
GM: He's very excited, I think, to be working in a year where

660 we've got Utzon with us again and he is keen to push some of these building projects so there's a corporate will at the moment to be doing some of these projects. Over here [on the organisational chart] we've got the Trust committees, there is a number of these; we've got the conservation

665 council, that has some Trust members, some executive members and some members of the general public. They really administer this conservation management plan. In any of these building projects, we have to have a heritage impact statement to get approval of the NSW heritage office

670 and really report back to the conservation council that we're doing everything in accordance with the conservation management plan.
There is another committee that is called the Risk Committee. They worry about money and not overspending

675 ... interference between different things like building might interfere with running shows; that sort of thing.
AMDS: Ok
GM: My job is really...the majority of my time is how to build this and still let them run shows down there.

680 AMDS: Like you have to drill when the music is playing very loud
GM: Then there is another committee called the Building Committee. So we have three Trust members and three executive members. And that is really the committee that approves all of the detailed activities in the building projects.

685 It is quite a good structure, there is a hierarchy and a good level of governance, I can't just run of and do whatever I want to do, I've got to get through levels and get all sorts of approvals, really. As you can understand that is important

690 for a building like the Opera House, you need that.
You mentioned the acoustics before. On the concert hall and the Opera Theatre, I suppose they were the first two consultants appointed to each of those projects and they are all fairly keen in driving the direction of the project. The

695 acoustics really drove the realisation that what we were planning for the Opera Theatre wasn't going to work. And for the concert hall it has really driven us to where we are with this stage idea – it has been quite an important element of the whole project. So, I hope it is of some assistance.

700 AMDS: It is.
GM: With the Utzon involvement, it has really turned out to be a team of three; there is Richard Johnson here in Sydney, Jan Utzon back in Denmark and Jorn in Denmark. Jorn is too old to travel so if there is anything required here,

705 Jan will fly out. Richard will go to Denmark once or twice a year to meet with Jorn Utzon, a lot of stuff gets transmitted by email and they've the software up there to be able to look at TriForma drawings and they'll have telephone conferences, video conferences. We have some theatre

710 planning consultants and acoustic consultants in London so occasionally they'll come to Sydney
AMDS: it is very international. And how often do they present to you then?
GM: In developing up this concept design there was

715 one trip to London from the Sydney people and the one from London would come to Sydney twice so about three meetings they had in a period of eight or nine months. And then separately Richard Johnson would go over to Denmark and just sit quietly with Jorn and Jan and work through all

720 the designs. So it seems to work. Back in the sixties when they did it I think they used to put drawings on plains and boats. At least where we are now, it's a lot quicker. Not a bad way of working.
AMDS: Would it be possible for me to take this.

725 GM: You can take that. I hope this has been to some help.
AMDS: It has, certainly. It has given a lot of clarity to understand the organisational structure.
GM: If you need anything else just give me a call

730 AMDS: Thank you very much, I will.
GM: Here's my card, I'm just going to put my correct email-address in here. We changed the name of the group last year
AMDS: OK
GM: It's Building Development now, it used to be Venue

735 Improvement
AMDS: ok
GM: because we picked up a wider responsibility. It wasn't just the venues.
AMDS: ok, thank you and goodbye for now

740

Interviewee: Joseph Skrzynski, former CEO of The Sydney Opera House Trust

Interviewer: Anne Marie Due Schmidt

Date: February 3 2005

5 Location: Meeting room CHAMP & CHAMP Ventures, Sydney Office

Notes: First and last minutes of interview missing due to technical problems

10

JS: ...all through the ministry of the arts. The chief executive of the opera house does report to the ministry of the arts. The Trust, if they wanted to, could just ... I think everybody would be a bit disappointed but there was a period where there wasn't a whole lot more to it than that. Now, I am a very practical sort of person and in our business here we do [vege-] capital equity.. I don't know whether you know what that means?

AMDS: No, not really.

20 JS: It is funding of ideas. So it is not money for...it is not investment in stock exchange, which is already grown up companies, it's about younger companies, who are not yet fully grown up, with good ideas. So we have to work out whether the ideas are good and under which conditions will the ideas succeed and so: 'can we get them money under those conditions to make it all work?'

AMDS: Ok.

30 JS: So it is a catalytic role between the world of ideas and the world of resources. So that is what I like doing....joining the dots. And I have had a life-long interest in the world of arts from the early days where I was treasurer of the student union at the University of Sydney – funding the university theatre society, the film society and so on – and eventually I married my wife who is a theatre director. In

35 Popov broadway theatre, not musicals and mainstream but alternative. So I've always had an interest in art. From Opera companies to dance companies to film and so on. All of it voluntary in my past-time, so I was always in the business but had a very active life in the arts so when they asked me to become chairman of the house I knew a lot about the Opera house from the artist's point of view and I knew his view. I held the conception that its very beauty was its problem; that it was so beautiful and so loved that nobody expected it to also be efficient. It was a trap. It is,

40 well you know, as you say about a beautiful boy that he gets more opportunities than a not so good-looking boy. It shouldn't be like that but it is like that in the world. So it occurred to me that the artists of the house and everybody else had accepted that the function of the opera house wasn't of the same standard as the architecture. So that was the challenge. To reconnect it and say 'how can we make it the best house?' And very soon after that analysis we were coming up to its 25th birthday of the opera house – from when it was opened, not from when it was conceived

45 – and that became sort of the challenge to think 'what does that mean?' Do we just have a party or you could say 'that is a quarter of a century, what is the rest of the century

50

55

going to be like? And are we getting ready to that?' So we took more of that view of it, we celebrated, but it was more about the future.

60

AMDS: But wasn't there also these thoughts about that it needed renovation and that it needed to be up to date?

JS: To an extent, it wasn't anything done that would need the building closed for a certain amount of time. But when you look at it in a 25-year view you suddenly become aware that obsolescence becomes more and more of a problem.

65

AMDS: Yes

JS: But as importantly we realised that the building had a difficult birth, as you know, and that the outside was drawn by one architect and the inside by another. And it wasn't really a good mix, so apart from the functional issues there was the aesthetic incongruity and that led to what you might almost call a bad 'spell' of the house in the eyes of the architectural profession. Nobody – with integrity – would want to touch it before that spell was removed. So that became a real issue especially as people believed that it should become world heritage listed. And, as you may know, when you heritage list something there is a documentation of the building and a management plan which defines how the building can be used in the future, what's important about the building and what mustn't be changed.

70

75

80

AMDS: Yeah.

JS: The existing conservation plan had been drawn up back in... shortly after the building was opened and it treated with equal importance that which was on the inside and the outside.

85

AMDS: Alright

JS: So with the heritage listing it'd be set in concrete for all time that the inside was just as important even though it was wrong. So we said 'no, we have to get the inside right at least conceptually before we get a world heritage listing, otherwise it'll be frozen'.

90

AMDS: Yeah, then you can't change anything at all.

JS: And that was an interesting thought process. And equally here in the community of respected architects there were people who never forgot or forgave that Utzon had been removed from the job and their idea of getting it right was 'close the building down, we have the plans so we know how it's going to be done, take out all this rubbish that was inside and build it properly the way he had designed it and he'd still be here to supervise it.' So that was the intellectual...the intelligentsia if you'd like. And yet, in my opinion, that was not possible for a number of reasons.

95

AMDS: No.

105

JS: The functions had changed, number one, so they said 'that is not a problem, just lets go back to have the original functions'. The building was designed to have opera and theatre in the main hall and drama in the other hall. It also doesn't work for opera, the pit is too small but it is nonsense. If you want a building that lasts you can't have a drama theatre that is too small [not sure about that sentence!] All that has been discussed and I loved the challenge of that. The previous Trusts and management

110

115 had been scared of that debate, it was all too hard, and these were influential people who would always give the people spaces so as to say 'see it is working so there is no need to discuss it'. I am not blaming anybody, the Government did not want the controversy, so the question was how to have a discussion that was intellectually honest and get a consensus so that if we go to the Government, we have to go the Government and say 'you won't be embarrassed, we have a consensus. All the people who are serious and interested agree', so the first task was to get intellectual agreement about what was the right way to go. We had a very interesting dinner party that I put up in the Opera House with everybody who had a strong point of view. AMDS: [laughter] It's a good idea to invite those people! JS: Yeah! There was a lot of talk, not a debate in a public hall but a private meeting where I met some of the people so as they could form their own opinion as to whether we had an honest intention to do something properly or whether this was just some campaign to try to shut them up or whatever. Obviously people decided to trust the experiment and there was a very important intervention in that process from Alex Popov, who was married to Lin Utzon for a period and in now a well-respected architect here in Sydney. AMDS: Ok, that is where I know his name from JS: Yep. And he was very important in a way that I'll describe in a moment. But the main thing was actually to get people to think not of the past but of the future and to put through the idea that we had to have a planning concept that would be good for the next five hundred years because with a building of this kind there is no reason to believe that it is not going to be there the next five hundred years. AMDS: No. JS: So the importance of having Utzon alive wasn't to go backwards but to go forwards. And that function...to accept that the arts, partly propelled by the Opera House, had grown so much that it was physically impossible to have the Ballet, the Symphony and the Opera Company occupy one hall for 52 weeks because their seasons add up to about 80 weeks. So physically the seasons won't fit. Because the Opera and the Ballet occupy the hall 52 weeks, well 48 weeks and the symphony will only be gone 26 weeks each year and subset argument: it is not at all sure that a proscenium arch concert hall works all that well – and that was the Utzon idea. He was fulfilling a client's wish instead of saying 'this is what must happen' so he was responding to a client's wish and trying to make it work. But asked, by himself "would you really want a symphony into a proscenium arch hall?" that answer is probably no. So there is nothing sacrilegious about going back to the plans in the respect that those plans respected a client-brief, the client-brief has changed. We should be looking at Utzon-inspired interiors for the new client-brief, not going back to plans in themselves. AMDS: Yeah. JS: So after two bottles of wine [laughter] there was sort of an agreement that it was what we were going to do. But what about Utzon? And that is where Alex said 'well, I've have to tell you, I have talked to him and he would be completely bored if you said 'Mr. Utzon, can we please go to those basement-cells that Jan's office has, dust of the drawings, no more work just build it the way it was.' It would be completely boring. Where would all the action be? Obviously thirty years later... AMDS: ...you would look at your plans with completely new eyes... JS: You would. And your plan in the detail, not the concept but the detail, reflect the materials available to you at that time. And today the materials are completely different. So your solutions had different parameters. So from your perspective with tectonics you could actually implement the vision in a completely different way so why would you go back. And on a literal level, the plywood-factory no longer exists and no-one makes plywood like that anymore. So when we came to the sweet course everybody agreed. The proposal was that we engaged him first and foremost to do a document which we might call the master plan of the conceptual part of the opera house as a document that would go into the national plan of the would heritage listing. So that doesn't describe 'how is' but 'what should be'. AMDS: that is the Design Principles? JS: Yes, that's it. At a concept level, that doesn't go back to the plans that are in the Mitchell library in his personal files and then you can consult if you want to know the right angle of something or the right colour but this is the concept at a very high level, the design principles, so that if we get it right what should it feel like. AMDS: Yes JS: And, as you'll know if you get to meet him, he is a very discursive sort of man. He is not a French sort of architect with didactics and theories. You've got to watch the way with the hand half the time [gesturing in the air to describe a shape], instead of words. He is a very plastic man, an artist, not theoretical so the design principles will probably have a discursive, relational and illustrative role rather than a hard-edge theory. And that reflects the person. That was a key platform. So coming back to the role of the Trust, it was defining that as custodians of one of the great icon-buildings of the second half of the 20th century and that we had a responsibility with austerity to set up the framework to take proper care of the building within a system of the original aesthetic state. Therefore to re-engage Utzon to write that master design document had to be the first step to be made. Politically it made sense to say 'look, you don't have to close the building down and spend 500 million while doing it and when it's finished it'll come out sort of ok, but not really'. No, no, we are just going to Utzon and get a master plan for all the future work of the building. It draws the poison from the situation by bringing him back, the controversy dies on that point and then we see; over time we develop the ideas of what should happen. And second point we agreed that we do know the interior.

When you have a master plan and you come to the function, people do listings of the existing elements but when you come to their point of obsolescence you replace them with elements that are in conformity with the design principles. So that is being real-politic about public funding. [what he means is that instead of refurbishing the whole lot at once, you refurbish every piece, when they are anyhow obsolescent]

AMDS: instead of changing it all at one time.

JS: And it solved that they didn't have to close the building down for five years, so progressive improvement of the building and progressive conformity with the design principles became our strategy. It sounds simple but it took a long time to put to record.

AMDS: Yes, I could imagine.

JS: It was around that time that I met Lin Utzon through an artist friend of mine called [Or Chald] and started the process of how do we get to Jorn Utzon to get his trust and see whether he would be interested in that approach. To come back and say we need this holism of yours, you can't just start with one room because how does it fit with everything else, then? Where do you start, you can't just begin in the corridor and do a door here and another door here and sort of go 'fix those doors, fix that glass,' so by doing the design principles it allowed us to start this relationship with him. We appointed Richard Johnson, allowed him to win Utzon's trust over an extensive period of discussion

AMDS: yes, they met several times

JS: and for Richard to become marinated or steaked in or immersed in the Utzon design philosophy then they could be ready to start working together, no matter if took six weeks or six months - it was actually a bit over two years

AMDS: and how come it was him?

JS: why it was Richard?

AMDS: yes

JS: Well as part of the 25th we, looking backwards to inform the flaws, we realised that a whole lot of little things had happened over the 25 years, which were individually not important but did not have a guiding hand. So when they decided to change the carpet they chose a green carpet, here they change the lamps and here the furniture. Little by little the coherency disappears because there wasn't an architect involved. So management just had a project and did this and did that. So appointing a master-architect to supervise that everything would conform was a part of the package anyway, so. And then to bring Utzon back to state the principles and work with a local architect to do many jobs and come along with the program.

So we had an urban competition and Richard was the most impressive. It's not in the tectonic, it's funny that you say that because the buildings he has worked on previously, you must go and have a look at some of them, Port Macquarie Centre here, I don't know whether you have seen it?

AMDS: No, but I will

JS: You'll see that they are very rectilinear, very fine proportions so in the interviews we did when we were

selecting the architects I said 'so, explain that to me, your vocabulary seems to be very rectilinear'. He was with Denton, Corker and Marshall at that time, now he has set up his own company, but all the buildings were plates and posts, no other elements, 'we'll just stick to plates and posts' so he said 'if it's not rectilinear, it is just a bent plate'

AMDS: well, that is true [laughter]

JS: so he convinced me that he could bend plates; that they didn't have to be straight. So anyway, clearly he was the one who had the most serious intent and I guess there is a philosophical fork on the road if you work on a historic building – do you work within the style of the historic building and pretend that it is original so that the visitor does not know whether this is build in 1880 or 1980 and there was a convention, I don't remember the name but some convention within architecture that starts with a d, where you actually step out and you don't try to fool people that it's original but you build it in today's vernacular and you find that very high order principle rather than the literal. Like the pyramid in the Louvre is no attempt to...

AMDS: no, no, it's not a mimic of what was there

JS: So when you look at the Opera House it is not as historic but if you do other thing in that, do you work within the vernacular and treat it as a historic building? Some of the architects, I think, were looking to put their own fingerprints on it but Richard was very much of the school that 'we don't know where to start so that's ...' and when you meet them you'll see that they are very, very serious and I think Richard has been terrific and has made a huge effort to get under the skin of Utzon and leave Richard Johnson over there [in the corner] to do other projects.

And the project that I think you should look at is the toilets in the lobby because that was a project we started before we appointed Richard before we finished the design principles with Utzon. It was something that was out of sequence in one sense. I don't know whether it is as important to you but all the building codes are designed by me. And one of many concerns was to have enough toilets. So that was a project that we were going to change and that was a project that had been on the way for two-three years and I said we'll start with these. And Richard Johnson did some plans and when he was happy with those he was working on them and started perfecting them until he looked at the principles and 'no, that's wrong' and he started again and looked at the principles and said again 'no, this is wrong' and it was not until the third or fourth time that he finally got it - how the design principles were going to inform the design of something as simple and functional as the toilets. If you meet him, ask him to get those drawings out and maybe discuss with him the evolution of the process. So it was the first step where Utzon wasn't involved in the detail because at that stage he was concerned with the design principles, but then Richard's final set got his approval. But in the meantime he was struggling to apply the principles to his design. It was a terrific, practical test to run and not just a theory of writing down the statements so it is actually something that you

might look at.
 I guess I'm covering why we did it...my role on the Trust, is
 345 that covered?
 AMDS: yes, that is covered. How does it work with who
 is appointed? I mean of course it is not random who is
 chosen, but...?
 JS: No. It is the Minister of the Arts. And he has to put it up
 350 to Cabinet and the whole Cabinet has to agree and then
 it is a Government issue, about the signing of the papers,
 but it is actually the premier of the state and the senior
 ministers of the cabinet who will get the list put out by the
 Minister of the Arts and in this Government the Minister of
 355 the Arts and the Premier is the same person.
 AMDS: Ok.
 JS: and he has an arts adviser, [name] and I was at a party
 where I met him
 AMDS: 'would you like to...' [laughter]
 360 JS: You know, you can't say no.
 AMDS: No.
 JS: But why, I don't know but I think somebody that I've
 worked with in the arts, a theatre consultant, would have
 recommended a strategic approach to the design. It was
 365 a new government and that government has been there
 the whole time while I have been here. It was a three
 year appointment initially and they extended it - you can't
 do more than three terms so I did it for nine years. This
 government was happy with what I was doing we solved
 370 a lot of problems too. And on the operational service we
 solved a lot as well. There was very bad unionism there.
 I am not against unions but I am against old-fashioned
 protection of in-efficient work in the name of unionism.
 What was worrying me was that performance artists often
 375 weren't in unions, their unions are very weak and they are
 generally contracted for short seasons. Whereas the stage
 staff and the technical support staff had full-time jobs
 through a combination of weak management and very old-
 fashioned unionism a very unhealthy situation had arisen
 380 where the cost-structure of the operation of the Opera
 House had gone up and up and up. And the subsidies from
 the Government to pay for that comes out of the same pool
 of money that also pays for performing artists, so too much
 money was going to the backstage and not enough to the
 385 front-stage.
 AMDS: Alright.
 JS: So the singers and dancers were earning on average
 perhaps 25-35 thousand dollars [app. 12.000kr/måned]
 a year probably for a season of 26 weeks and they would
 390 be waitresses or working in supermarkets the rest of the
 year – a situation that is normal in arts – and that is after
 five or six years of intensive study at the best institutes
 in Australia and even after a 25 year carrier they still only
 earn this amount. And on the other hand you have people
 395 with no qualifications what so ever earning 70.000 dollars
 a year. I am not saying that these people should earn 30
 and these people should have 50, but there should be a
 more healthy relationship. And there are too many of them
 because of the union-rules we had to engage them for eight

hours, we never needed them for eight hours. When you
 400 are booking a show in you are rehearse you need about
 twelve hour blocks, you work all night the three days before
 the show opens. Once the show opens, you only need them
 for four hours: one hour before the customers come, two
 hours for the show and an hour afterwards. So we rarely
 405 need them for eight hours. In the six weeks that the show
 is running, we are paying for three hours we can't use, they
 sit around in the back and drinking and falling over and
 being drunk and playing with the equipment and not being
 engaged. And secondly: you need to have eight of them on
 410 a shift. One to pull the rope, one to do the switch, 'I can't
 do this, I can only do that'. So over the nine years we've
 broken those habits so we were able to...do a bit of a re-
 aging of the staff because a lot of the staff came from the
 construction site. So they were builders who became the
 415 ones who were operating the building. And they brought
 construction-industry ideas into how to run the building.
 Ideas such as if the weather forecast said that it was going
 to be nice weather, you start yearly, at seven, you finish at
 four and you are in the pub at the beach by five. You have
 420 got another three hours of sun-bake. If you are Australian
 you have the stamp that you have to be off at four and if
 you have to stay longer than four 'well, then you pay me
 double, I want to be at the beach at four o'clock'. It is alright
 when you are building but it doesn't really work in an Opera.
 425 So everything that happened at night-time between four
 and six o'clock was overtime 10% extra after four o'clock
 and another 20% after six o'clock. When I began in 1998
 we still had those sorts of rules. Without any revolution,
 without locking people out, just by working with the union,
 430 ageing people out, not firing but retiring, trimming things
 down we spend million of dollars a year on training, giving
 people certificates of competency so that if they left the
 Opera House and went somewhere else they could get
 acknowledged for their skill. We were the first operating
 435 business to be certified by the Australian educational
 sector and the universities to give proper certification of
 production skills or technical skills. It took the purpose
 away with how many hours you get paid for and introduced
 competency and paying for skills and paying people more if
 440 they invested. You are having four people instead of eight;
 you only need four if they can do everything.
 So getting the money safe on that and putting the money
 back into the content. So coming back to the role of the
 Trust, it had in the 90ties become more like a landlord, like
 445 a shopping centre. We would stand back and collect the
 rent but not have an engagement with the content. So now
 we are more like curators, not like landlord. We should have
 a partnership with the performing companies and respect
 that we have a certain historical pattern with the companies
 450 and there is a certain pattern in Government funding
 [...] with that said, we are however also saying 'we have
 a certain amount of money and with what is happening,
 what is not happening. Who are not being represented in
 the house' and really use our money to commission work
 455 which extends the art form of representation and extends

the audience reach. So we become pro-active so we take on a curatorial role over the whole, over the year, in artform, in representation, in experimental and conservative

460 linear so we have a sum of money to give to the Opera companies to take on something a bit more risky on the audience or bring in experimental theatre which was a first in the Opera House. New music. So we build the studio is a very important for that sort of work and we've got a

465 price-setting on it which is 25 dollars a show which is a huge difference to the 52 to 150 in the large halls, so it is another audience. And we have now commissioned works of younger and more experimental artists and aboriginals and Chinese and all the other immigrants sectors that we

470 reach out to.

AMDS: So it is much more open

JS: Much more open and it is important to mention that because when we came to Utzon we said 'ok, the original design had two big halls, you come onto the podium'...

475 you've probably read the theory.

AMDS: yes

JS: 'but after you left and they took the ballet and opera and put it in that hall, the stage machinery wasn't needed so they build – there was a recording studio originally but

480 they build the play house and the drama theatre. So the principle is sort of 'ah, ok, there can be performing spaces in the podium as well' so in the long-term, 500 years, there was the discussion of do we eventually get rid of these and not having those shows? So there was the whole discussion of the function of the building. And he asked a lot of

485 questions about the scenes, what they do, how do they work. It was also his observation that, more generally, the Opera House has become more complex - rather than those halls standing alone. And it seems to work better because

490 there was an interaction, a balance because without the big halls, the big audiences, there would never be the more experimental things going on. So the question became, let's make it work. Because the way they were set in there violated the Utzon principles and the way that all the scenes

495 were to be over the podium. When you arrive you go up the stairs and up between the shells in a way so you never lost the contact with the harbour setting and when you went into the hall you were almost in your seat row. Today when you go in, there is a labyrinth of cloakrooms, toilets

500 you don't know where you are. So underneath we had no foyers that opened to the outside, they were all internalised because the architects that were Utzon's successors understood the design principal of the podium so that it had to be massive hence you couldn't make a lot of holes in

505 it. You couldn't make glass foyers, so part of the challenge for the team was to dare to make changes to the outside. Previously they had separate little foyers and each their own entrances but each was separate. So if we are not going to get rid of those scenes how do we reconcile the fact that

510 the podium is supposed to be this massive thing and at the same time maintain the principle that whenever you go to the opera you are aware of the harbour setting right until you go into the auditorium?

So on my first trip to Denmark, Richard Johnson had gone there one time previously to establish professional contact to the Utzon office carrying a message that had got there by their daughter Lin to do the design principles so that we the next five hundred years could read it and understand it. And he was like 'how can I say no?' 515

JS: that was the second project he did for us, the first was the Utzon room – the old reception room – because it was completely self-contained so you could re-do the interior where there was no harmony between the old and the new and it was to be our pilot-project to demonstrate to the world and the government how it feels and looks like if you get it right - the lightings and the colours and the finishes on the floors and the walls. So that was to be our pilot-project and when it opened the premier came down and he was very impressed. And in the meanwhile we didn't stop with that project but continued to look at disabled access to the house and to the surrounding area outside. And then the next project was the opera theatre. So that is how he developed: the principles and then decided to take part of it and then went on to solve the functional problems inside. 520

JS: You have to have the space. Generically the solution was to create more space. If you can't go up, you can't go sideways, then you have to go down. And then that, which was a great acoustic solution because as the sails go like that, as you go down you get width so volumetrically you gain a lot. I think they gained 40% extra. Along with solving the volumetric problem it also solved a lot of other problems: the stage became wider and deeper and at that level below we could actually come back under the foyers underneath and the kitchens and we could look for a much bigger pit and have more seats and all the seats could all have good sightlines. So we solved a lot of functional problems with that central proposition. So we have to get them through the working level of the house all the way up here [close to the halls] and up to their seats. That was something that nobody, in the fifties, had thought about. We were all young people back then. When I say disabled it's not necessarily wheel chairs, knees, hips, kids in prams and so on. So this gives us the opportunity to address that disabled access problem as well as solving the acoustics and solving the size problems. It'll be funny now because instead of both sitting on the podium, one will be down a little bit to get the volumetric space that this one has by width. So the clarity of that concept...but he's a practical, he is not a French theoretician, where you are a complete prisoner of that theory once you've pronounced it, 'bang, that's a theory'. I think he is much more interested in the experience. About acoustics there is this lovely story; I don't know whether you've heard it, that is when we ask him what makes...or what is the perfect acoustics and he says that's the hall where the audience will clap the longest and the loudest. It is a typical way of saying 'don't get carried away with the technology, it is about the experience'. His approach, in my opinion, maybe I am pushing it a little bit too hard, but in my opinion he is, despite being an artist, that one would describe as an impractical person, he is a 530 535 540 545 550 555 560 565 570

very practical person. I think he is working very consciously to relate art with the industrialisation. He is looking for solutions that lend themselves to mass-production not a one-off. So his search for a resolution doesn't detract
575 from a current freedom of design but a clever one that can be resolved by minor components that can easily be mass-produced and assembled. It is a very, very interesting response to the industrialisation, I find.

BIBLIOGRAPHY AND ILLUSTRATION CREDITS

BIBLIOGRAPHY

- Abel, Chris (2004) *Architecture, Technology and Process*, Architectural Press/Elsevier.
- Alberti, Leon Battista (1988) *On the Art of Building in the Ten Books*, Translation: Joseph Rykwert, Neil Leach and Robert Tavernor, Cambridge Massachusetts, MIT Press.
- Allan, Stan and Foster, Hal (2003) *A Conversation with Kenneth Frampton*, *October Magazine*, 106, Fall 2003, pp. 35–58.
- An Interview With Mark Wigley (2002) *Architectural Theory Review*, vol. 7, no. 1, 2002, pp. 89-102.
- Andersen, Ib (2005) *Guide to Problem Formulation – For Research Projects within the Social Sciences*, Samfundslitteratur Press.
- Andersen, Ib et al (1995) *On the art of doing field studies : an experience-based research methodology*, *Skrifter fra Institut for Organisation og Arbejdssociologi* No. 18, Copenhagen, Handelshøjskolens Forlag.
- Andrews, Richard (2003) *Research Questions*, London, Continuum.
- Arup Acoustics (2003) *Benchmarking test of Sydney Opera House*, Opera Theatre
- Arup Acoustics Home (2005) [Internet] Available from: < www.arup.com/acoustics > [accessed July 25, 2005].
- Arup, Ove (1970) *The Key Speech* [Internet] Arup, London. Available from: < www.arup.com/DOWNLOADBANK/download5.pdf > [assessed 11 September 2006]
- Ashworth, H. Ingham; Martin, John Leslie; Parkes, Cobden; Saarinen, Eero (1957) *Sydney Opera House Competition*, *The Architect and building news*, vol. 28, no. 211, pp. 274-281.
- Bachelard, Gaston (1964) *The Poetics of Space*, Boston, Beacon Press.
- Bacon, Francis (1961) *Essays 1561-*, Translation by H.C. Huus, Copenhagen, Rosenkilde & Bagger.
- Banham, Reyner (1960) *Theory and Design in the First Machine Age*, The University Press, Glasgow
- Barron, M (1983) *Auditorium Acoustic Modelling Now*, *Applied Acoustics* 16, pp. 279-290.
- Barron, M and Chinoy, C. B. (1979) *1:50 Scale Acoustic Models for Objective Testing of Auditoria*, *Applied Acoustics* 12, pp. 361-375.
- Barron, Michael (1993) *Auditorium Acoustics and Architectural Design*, Bath, E & FN Spon.
- Barron, Michael (2000) *The current state of acoustic design of concert halls and opera houses*, *Proceedings Acoustica*, Madrid 2000.
- Baume, Michael (1967) *The Sydney Opera House Affair*, Thomas Nelson Ltd, Sydney.
- Beesley, Philip and Seeböhm, Thomas (2000) *Digital Tectonic Design*, *The 19th International Education in Computer Aided Design in Europe (eCAADe) Conference*, Hannover 2000, pp. 287-290.
- Beim, Anne (1999) *Tectonic Visions in Architecture – Investigations into practices and theories of building construction. Six case studies from the 20th century*, Copenhagen, Royal Danish Academy of Fine Arts, School of Architecture.
- Beim, Anne (2004) *Tectonic Visions in Architecture*, Copenhagen, Royal Danish Academy of Fine Arts, School of Architecture.
- Benevolo, Leonardo (1996) *History of Modern Architecture*, vol. 1 and 2, Third translated edition, Cambridge, Massachusetts, MIT Press.
- Betsky, Aaron (1997) *Machine Dreams*, *Architecture*, volume 86, no. 6, pp. 86-91.
- Bolton, Robert (2001) *Floating the Opera House*, *Australian Financial Review*, Section: News, July 01, p. 80.
- Borum, Finn (1998) *Det kvalitative interview som metode til organisationsanalyse [The qualitative interview as a method for organisational analysis]*, MPA Working Paper no. 9, Copenhagen Business School.
- Bötticher, Carl (1844) *Die Tektonik der Hellenen*, Potsdam, Riegel.

- Bötticher, Carl Gottlieb Wilhelm (1846) *The principle of the Hellenic and Germanic Ways of Building with Regard to Their Application to Our Present Way of Building*. In: Hermann, Wolfgang (translation 1992) *In What Style should we Build? The German Debate on Architectural Style*, Chicago, Getty Center, University of Chicago Press, pp. 147-168.
- Bourdieu, Pierre (1977) *Outline of a theory of practice*, Cambridge, Cambridge University Press.
- Bourdieu, Pierre (2005) *Viden om Viden og refleksivitet [Knowledge about knowledge and reflexivity]*, Hans Reitzels Forlag.
- Broadbent, Geoffrey (1967) *Book of proceedings from symposium on Architectural method in Portsmouth, 4th 5th and 6th December 1967*.
- Broadbent, Geoffrey (1988) *Design in Architecture – Architecture and the Human Sciences*, 8th edition revised reprint, London, David Fulton Publishers.
- Brox, Ottar (1998) *Praktisk samfunnsvitenskap [Practical social science]*, 2nd edition, Oslo, Univesitetsforlaget.
- Building Program at Sydney Opera House (2004), Sydney Opera House Website <<http://www.sydneyoperahouse.com>>, Media release, March 5.
- Cache, Bernard (2002) Gottfried Semper: stereotomy, biology and geometry, *Architectural Design*, Vol 72, pp. 28-33.
- Callon, Michel (1994), *Society in the Making: The Study of Technology as a Tool for Sociological Analysis* In: Bijker, Wiebe E. et al (1994) *The Social Construction of Technological Systems – New Directions in the Sociology and History of Technology*, Cambridge, Massachusetts, MIT press, Massachusetts Institute of Technology, pp. 83-103.
- Carter, John (1967) *The Sydney Opera House – What went wrong?*, Royal Institute of British Architects Journal, February, vol. 74, pp. 55-63.
- Casey, Edward S. (2000) *Imagining – a phenomenological study*, Indiana University Press, Bloomington
- Castells, Manuel (1996) *The rise of the Network Society, The Information age, economy and culture*, volume 1, Cornwell, Blackwell Publishers.
- Chen, Sheng-Chih (2001) *Analysis of the use of Computer Media by Expert and Novice Designers* In: *Proceedings of CAADRIA 2001*, Edited by Gero, John S.; Chase, Scott and Rosenman, Mike, Key Centre of Design Computing and Cognition University of Sydney.
- Christiansen, Karl, (1994) *Arkitekturkonstruktioner – refleksioner mellem æstetik og teknik*, [Architecture-art-construction – reflections between aesthetics and technique], Århus, Denmark, Arkitektskolen i Århus.
- Chupin, Jean Pierre (2005) *The Tectonic Bug*, *Architecture and Ideas*, 5, 1, pp. 66-80.
- Clouds: Jørn Utzon (1994) Directed by Pi Michael. Søborg, Danmarks Radio.
- Colquhoun, Alan (1984) *Three Kinds of Historicism*, In: Nesbitt, Kate (ed.), *Theorizing a new agenda for architecture – an anthology of architectural theory 1965-1995*, New York, Princeton Architectural Press, 1996, pp. 202-209.
- Colquhoun, Alan (2002) *Modern Architecture*, Oxford History of Art, Oxford University Press.
- Cook, Mike (2004) *Digital Tectonic. Historical Perspective – Future Prospect*, In: Leach, Neil; Turnbull, David; Williams, Chris (eds) (2004) *Digital tectonics*, UK, Wiley-Academy, pp. 40-49.
- Cremer, L. and Muller, H. (1982) *Principles and applications of room acoustics*, Applied Science Publisher, London and New York.
- Crisp, Lyndall (2002) *Make-over Putting the house in order*, Australian Financial Review, Section: News March 21, p. 57.
- Davey, Peter (1997) *Democratising the tectonic*, *The Architectural Review*. October, Vol. 202, Iss. 1208, pp. 4-6.
- Davies, Colin (1996) *Expressive potential*. *The Architectural Review*. London, April, Vol.199, Iss. 1190, p. 96.
- DeLanda, Manuel (2004) *Material Complexity*, In: Leach, Neil; Turnbull, David; Williams, Chris (eds) (2004) *Digital tectonics*, UK, Wiley-Academy, pp. 14-21.
- Deleuze, Gilles (1995) *The fold – Leibniz and the Baroque*, London, The Athlone Press.
- Drew, Philip (1972) *Third generation – the changing meaning of architecture*, London, Pall Mall Press.
- Drew, Philip (1995) *Sydney Opera House*. Jørn Utzon, *Architecture in Detail*, Phaidon, London.
- Drew, Philip (1999) *The Masterpiece: Jorn Utzon - A Secret Life*, South Yarra, Hardie Grant Books.
- Duek-Cohen, Elias (1967) *Utzon and the Sydney Opera House – statement in the public interest*, Sydney, Morgan Publications.

Eiler Rasmussen, Steen (1957) *Experiencing Architecture*, Massachusetts, MIT Press.

Elliot, Brian ed. (1988) *Technology and social process*, Edinburgh, Edinburgh University Press.

Erhvervsfremme Styrelsen (2000) *Byggeriets fremtid - fra tradition til innovation* [The future of building – from tradition to innovation], Erhvervs og byggestyrelsen, [Internet], Available from: www.ebst.dk/publikationer/rapporter/byg_frem/index.html [Accessed March 24th, 2006].

ESSERT, R. (1997) Progress in concert hall design – developing an awareness of spatial sound and learning how to control it, *EBU Technical Review*, Winter 1997, pp. 31-39.

Faist A., Citherlet S., and Pasquale D (1997) ACOUSALLE, a computer program with expertise for the planning and analysis of the acoustics of indoor spaces, *Advances in Engineering Software*, 28, p. 211-216.

Feldthaus, Per (2003) *Ud af elfenbenstårnet* [Out of the ivory tower], *Arkitekten*, volume 106, no. 3, march, p. 34.

Felmban S. M. and Oldham D. J. (2003) The development of an expert system for the design of auditoria, *Proceedings of the Tenth International Congress on Sound and Vibration*, 7-10 July 2003, Stockholm, Sweden, pp. 4749-4756.

Floyd, Carol and Collingwood, Julia (2000) *The Sydney Opera House*, New Holland, Sydney.

Flyvbjerg, Bent (1987) 'Theory' and method in the study of human beings and society: the possible and impossible scientific character of studies of human beings and society, *Institute of Development and Planning*, Aalborg University.

Flyvbjerg, Bent (2005) Design by deception - the politics of megaproject approval, *Harvard Design Magazine* 22, pp. 50-59.

Flyvbjerg, Bent (2006) Five Misunderstandings About Case-Study Research, *Qualitative Inquiry*, Vol. 12, No. 2, April, pp. 219-245.

Forty, Adrian (2000) *Words and buildings – A Vocabulary of Modern Architecture*, London, Thames and Hudson.

Frampton, Kenneth (1974) On Reading Heidegger, In: Nesbitt, Kate (ed.) (1996) *Theorizing a new agenda for architecture – an anthology of architectural theory 1965-1995*, New York, Princeton Architectural Press, pp. 442-446.

Frampton, Kenneth (1980) *Modern Architecture: A critical History*, London, Thames and Hudson.

Frampton, Kenneth (1982) *Avant-garde and continuity*, In: Kenneth Frampton (ed.), *Modern Architecture and the Critical Present*, London, Architectural Design Profile, pp. 20-27.

Frampton, Kenneth (1983a) Prospects for a Critical Regionalism, In: Nesbitt, Kate (ed.) (1996) *Theorizing a new agenda for architecture – an anthology of architectural theory 1965-1995*, New York, Princeton Architectural Press, pp. 470-482.

Frampton, Kenneth (1983b) Towards a Critical Regionalism, Six Points for an Architecture of Resistance. In: Foster, Hal (ed.) *The Anti-Aesthetic, Essays on Postmodern Culture*. Port Townsend, Washington. Bay Press.

Frampton, Kenneth (1990) *Rappel à l'ordre, the Case for the Tectonic*, In: Nesbitt, Kate (ed.) (1996) *Theorizing a new agenda for architecture – an anthology of architectural theory 1965-1995*, New York, Princeton Architectural Press, pp. 518-528.

Frampton, Kenneth (1992) The Atrium as Surrogate Public Form, *Proceedings from The Jerusalem Seminar in Architecture, Technology, place & architecture*, June 9-11 1996, pp. 272-273.

Frampton, Kenneth (1995) *Studies in Tectonic Culture - The Poetics of Construction in Nineteenth and Twentieth Century Architecture*, Cambridge Massachusetts, MIT Press.

Frampton, Kenneth (1996) Introduction, *Proceedings from The Jerusalem Seminar in Architecture, Technology, place & architecture*, June 9-11 1996, pp. 12-15.

Frampton, Kenneth (2001) Chapter 8: Bötticher, Semper and the Tectonic: Core Form and Art Form, In: Ballantyne, Andrew, *What is architecture?*, Routledge, pp. 138-152.

Frampton, Kenneth (2002) *Labour, Work and Architecture – Collected Essays on Architecture and Design*, Phaidon Press.

Frascari, Marco (1984) *The Tell-the-Tale Detail*, VIA no. 7, Graduate School of Fine Arts, University of Pennsylvania, pp. 22-37.

Frascari, Marco (1991) *Monsters of Architecture – Anthropomorphism in architectural theory*, Rowman & Littlefield Publishers, Maryland.

Fromonot, Françoise (1998) *Jørn Utzon. The Sydney Opera House*, Electa/Ginkgo, Milan.

- Gao, Wan-Ping (2004) *Tectonics? A Case Study for Digital Free-form Architecture*, Proceedings of Computer Aided Architectural Design Research in Asia, Younsei University Press, Seoul, pp. 519-534.
- Gibbons, Michael et al (1994) *The New Production of knowledge – The dynamics of science and research in contemporary societies*, London, Sage.
- Giedion, Sigfried (1941) *Space, Time and Architecture*, In: Bek, Lise and Oxvig, Henrik (eds) (1997) *Rumanalyser [Spatial analysis]*, Arkitekturtidsskrift B, Aarhus, pp. 253-270.
- Giedion, Sigfried (1965) *Jörn Utzon and the Third Generation – A new chapter of "Space, Time and Architecture"*, Zodiac 14, pp. 36-47.
- Gillespie, Norman (2005) *Interview with the author May 5 2005*. Sydney Opera House, Sydney. [Recording in possession of author].
- Glahn, Else (1984) *Yingzao Fashi: Chinese Building Standards in the Song Dynasty*, VIA no. 7, Graduate School of Fine Arts, University of Pennsylvania, pp. 89-102.
- Goad, Philip (1997) *An Appeal for Modernism: Sigfried Giedion and the Sydney Opera House*, Fabrications, vol. 8, pp. 129-145.
- Gregotti, Vittorio (1983) *The Exercise of Detailing*, In: Nesbitt, Kate (ed.) (1996), *Theorizing a new agenda for architecture – an anthology of architectural theory 1965-1995*, New York, Princeton Architectural Press, pp. 494-497.
- Häggström, Cecilia (1999) *Designforskningsens möjligheter [The possibilities of Design Research]*, Nordisk Arkitekturforskning, vol.12, no. 3, pp. 7-12.
- Hale, Jonathan (2000) *Signs of resistance: re-membling technology*, The Journal of Architecture, Volume 5, Spring, pp. 91-97.
- Hale, Jonathan A. (2000) *Building ideas – an introduction to architectural theory*, Chichester, John Wiley and Sons.
- Hale, Patricia and Macdonald, Susan (2005) *The Sydney Opera House: An Evolving Icon*, Journal of Architectural Conservation, July, Vol. 11, No. 2, pp. 7-22.
- Hall, Peter (1986) *Function is not a dirty word*, In: Yeomans, John (1968) *The other Taj Mahal – what happened to the Sydney Opera House*, Plymouth, Longmans, Green and Co.
- Ham, Jeremy (2003) *The computer as a tectonic design tool: Comparisons between virtual and actual construction*, Digital Design: The 21st International Education in Computer Aided Design in Europe (eCAADe) Conference, pp. 265-268.
- Hartoonian, Gevork (1986) *Poetics of Technology and the New Objectivity*, Journal of Architectural Education, vol. 40, no. 1, Autumn, pp. 14-19.
- Hartoonian, Gevork (1997) *Modernity and Its Other – A Post-Script to Contemporary Architecture*, Studies in architecture and culture no. 3, Texas A&M University Press, College Station.
- Heidegger, Martin (1962) *Being and Time*, Harper & Row, New York.
- Heidegger, Martin (2002) *Til sagen for tænkningen [To the point of reasoning]*, Aarhus, Philosophia.
- Henriksen, Lars Bo et al (2004) *Dimensions of Change – Conceptualising Reality in Organisational Research*, Copenhagen, Copenhagen Business School Press.
- Jabi, Wassim (2004) *Digital Tectonics: the intersection of the physical and the virtual*, Proceedings of the 2004 Conference of the AIA Technology in Architectural Practice Knowledge Community, eds. S. Williamson, P. Beesley and N. Cheng, ACADIA, Cambridge (Ontario), pp. 256-269.
- Jamison, Andrew and Hård, Mikael (2003) *The Story-lines of Technological Change: Innovation, Construction and Appropriation*, Technology Analysis and Strategic Management, no. 1.
- Joern Utzon's Visit to Sydney (1957) *Architecture in Australia*, July/september, vol. 46, pp. 62-63.
- Johnson, Pilton, Walker (2005) *Design Development Sydney Opera House*, Internal working document.
- Johnson, Richard (2005a) *Interview with the author February 15 2005*. Johnson Pilton Walker, Sydney Office, Sydney. [Recording in possession of author].
- Johnson, Richard (2005b) *Interview with the author March 02 2005*. Johnson Pilton Walker, Sydney Office, Sydney. [Recording in possession of author].
- Johnson, Richard (2005c) *Interview with the author July 21 2005*. Johnson Pilton Walker, Sydney Office, Sydney. [Recording in possession of author].
- Jones, Peter Blundell and Kang, Jian (2003) *Acoustic form in the Modern Movement*, Architectural Research Quarterly, vol. 7, no. 1.

- Jordan, Niels (2004) Interview with the author November 24 2004. Gevninge, Denmark. [Recording in possession of author].
- Jordan, Vilhelm Lassen (1980) *Acoustical Design of Concert Halls and Theatres – a personal account*, London, Applied Science Publishers.
- Keiding, Martin (2003) *Sydney, before and after*, Arkitektur DK, vol. 47, no. 8, pp. 483-486.
- Kemper, S. (2001) Practice: Anthropological aspects, In: Smelser, Neil J. and Baltes, Paul B., *International Encyclopedia of Social and Behavioral Sciences*, volume 17, pp. 11945-11948.
- Kerr, James Semple (1993) *Sydney Opera House – An interim plan for the conservation of the Sydney Opera House and its site*, Published by the Sydney Opera House Trust, Sydney.
- Kerr, James Semple (2003) *Sydney Opera House: a plan for the conservation of the Sydney Opera House and its site*, 3rd ed., Sydney Opera House Trust, Sydney.
- Keys, Peter (1965) *The Sydney Opera House*, *Architecture in Australia*, December, vol. 54, no. 4, pp. 72-92.
- Kolarevic, Branko (2001) *Back to the Future: Performative Architecture*, *International Journal of Architectural Computing*, volume 2, issue 1, pp. 43-50.
- Kolarevic, Branko (2003) *Information Master Builders*, In: Kolarevic, Branko (ed.) (2003) *Architecture in the Digital Age – Design and Manufacturing*, New York and UK, Spon Press, pp. 55-62.
- Kolarevic, Branko (ed.) (2003) *Architecture in the Digital Age – Design and Manufacturing*, New York, Spoon Press, Taylor & Francis.
- Kolarevic, Branko and Malkawi, Ali (eds.) (2005) *Performative Architecture: Beyond Instrumentality*, Routledge.
- Kragh, Helge and Petersen, Stig Andur (1981) *Naturvidenskabsteori – Træk af debatten om naturvidenskab, teknologi og samfund* [Theory of Natural Science – Outline of the debate concerning natural science, technology and society], Viborg, Nyt Nordisk Forlag Arnold Busck.
- Kruft, Hanno-Walter (1994) *A history of Architectural Theory – From Vitruvius to the Present*, Translated by Ronald Taylor, Elsie Callander and Anthony Wood, Zwemmer, New York, Princeton Architectural Press.
- Kvale, Steinar (1989) *Issues of validity in qualitative research*, Sweden, Studentlitteratur.
- Kvale, Steiner (1994) *InterView - An introduction to qualitative research interviewing*, Copenhagen, Hans Reitzels Forlag.
- Kvan T., Mark, E. Oxman Rivka and Martens, B. (2004) *Ditching the Dinosaur: Redefining the Role of Digital Media in Education*, *International Journal of Design Computing*, MIT Press.
- Latour, Bruno (1988) 'The Prince' for machines as well as for machinations, In: Elliot, Brian ed. (1988) *Technology and social process*, Edinburgh, Edinburgh University Press, pp. 20 – 43.
- Le Corbusier (1970) *Towards A New Architecture*, translation by Frederick Etchells, 4th printing, New York, Preager Publishers.
- Leach, Neil (2004) *Swarm Tectonics*, In: Leach, Neil; Turnbull, David; Williams, Chris (eds) (2004) *Digital tectonics*, UK, Wiley-Academy, pp. 70-78.
- Leach, Neil (ed.) (1997) *Rethinking architecture – a reader in cultural theory*, London, Routledge.
- Leach, Neil; Turnbull, David; Williams, Chris (eds) (2004) *Digital tectonics*, UK, Wiley-Academy.
- Lenz, U. (2000) *CAD og Design – hvordan påvirker det digitale medie arkitekturen*, [CAD and Design – how does the digital influence the architecture], KAARK, 02, AAA, Aarhus, Denmark.
- Liu, Yu-Tung (1998) *Where should architecture go in the computer era*, *CADesigner*, 123, pp. 36-39.
- Liu, Yu-Tung and Lim, Chor-Kheng (2005a) *New Tectonics: New Factors in Digital Spaces*, *Proceedings of Computer Aided Architectural Design and Research*, New Delhi, India pp. 45-59.
- Liu, Yu-Tung and Lim, Chor-Kheng (2005b) *New tectonics: a preliminary framework involving classic and digital thinking*, *Design Studies*, volume 27 (2006), pp. 267-307.
- Lobell, John (1979) *Between Silence and Light*, Shambala, Boulder.
- Lübcke, Poul (ed.) (2002) *Vor tids filosofi – Engagement og forståelse* [The philosophy of our time – engagement and understanding], 8th edition, Copenhagen, Politikens Forlag.

- Lund, Lene Dammand (2004) Teorigrundlag for byggeriet [The theoretical foundation for the building industry], Arkitekten, volume 106, no. 15, December 2004, pp. 38-39.
- Lynn, Greg (1996) Blobs, or why tectonics is square and topology is groovy, ANY 14, pp.58-61.
- Lynn, Greg (2004) The structure of ornament, In: Leach, Neil; Turnbull, David; Williams, Chris (eds) (2004) Digital tectonics, UK, Wiley-Academy, 62-68.
- Madsen, K.B. ed. (1980), Psykologisk Leksikon [Psychological dictionary], Copenhagen, Gyldendal.
- Mainstone, Rowland J. (2001) Developments in structural form, 2nd edition, Oxford, Architectural press.
- Mallgrave, Harry Francis (1989) Introduction, In: Mallgrave, Harry Francis and Herrmann, Wolfgang (1989) Gottfried Semper - The four elements of architecture and other writings, Cambridge University Press, Cambridge, 1989, pp. 1-44.
- Mallgrave, Harry Francis (1996) Gottfried Semper – Architect of the Nineteenth Century, Yale, Yale University Press, New Haven and London.
- Mallgrave, Harry Francis and Hermann, Wolfgang (eds.) (1989) Gottfried Semper - The four elements of architecture and other writings, Cambridge, original Cambridge University Press.
- Mandell, Julia (2004) Driven to perform: high-technology buildings with sophisticated environmental systems are becoming more common and changing the way architects and engineers work together, Architecture, volume 93, February, pp. 29-31.
- Marks, Kathy (2004) Sydney invites Opera House architect back for an encore and a facelift, The (London) Independent, February 10.
- McTaggart, Greg (2005). Interview with the author March 22 2005. Sydney Opera House Building Development, Sydney. [Recording in possession of author].
- Mikami, Yuzo (2001) Utzon's Sphere. Sydney Opera House – how it was designed and built, Shokokusha, Tokyo, Japan.
- Minutes of meetings 02.06.1962, unpublished, Mitchell Library Collection, ML MSS 2362/4, Sydney.
- Minutes of meetings 16.03.1961, unpublished, Mitchell Library Collection, ML MSS 2362/4, Sydney.
- Minutes of meetings 1958-1966, unpublished, Mitchell Library Collection, ML MSS 2362/4, Sydney.
- Minutes of meetings, 17.11.1960, unpublished, Mitchell Library Collection, ML MSS 2362/4, Sydney.
- Minutes of meetings, 30.06.1958, unpublished, Mitchell Library Collection, ML MSS 2362/4, Sydney.
- Mitchell, William J. (1995) City of Bits – Space, Place and the Infobahn, Cambridge Massachusetts.
- Mitchell, William J. (1989) Architecture and the Second Industrial Revolution, The Harvard Architecture Review 7, Cambridge, Mass., MIT Press, pp. 166-175.
- Mitchell, William J. (1990) The Logic of Architecture – Design, Computation and Cognition, Cambridge, Massachusetts, MIT Press.
- Mitchell, William J. (1999a) A Tale of Two Cities: Architecture and the Digital Revolution - influence of computer-aided design on construction, Science, volume 285, August, pp. 839-843.
- Mitchell, William J. (1999b) Antitectonics: The Poetics of Virtuality, In: Beckman, John (ed.) (1999) The Virtual Dimension, New York, Princeton Architectural Press, pp. 204-217.
- Mitchell, William J. (2004) Constructing complexity in the digital age - Beyond the ivory tower, Science, volume 303, March, pp.147-149.
- Mitchell, William J. and McCullough, Malcolm (1995) Digital Design Media, 2nd edition, Toronto, John Wiley and Sons.
- Mo, Linn (2003) Philosophy of Science for Architects, Trondheim, Kolofon.
- Morel, Matt (2005) Interview with the author February 22 2005. Johnson Pilton Walker, Sydney Office, Sydney. [Recording in possession of author].
- Mortensen, Bo (2005) Akustikken i Bagsværd Kirke [The acoustics of Bagsværd Church], In: Utzon Logbog vol. II, Bagsværd Kirke, Edition Bløndal, pp. 152-156.
- Mulhall, Stephen (1996) Routledge Philosophy Guidebook to Heidegger and Being and Time, New York, Routledge.
- Murray, Peter (2003) Opera dramatics, Architect's journal, 4/11 December, London, pp. 16-17.
- Murray; Peter (2004) The saga of the Sydney Opera House – The dramatic story of the design and construction of the icon of modern Australia, Spoon Press, New York.

- National Heritage Listing for Sydney Opera House (2005) Sydney Opera House Website [Internet]. Available from: <www.sydneyoperahouse.com/sections/media_room/media_releases/press_release.asp?idPressRelease=166&sm=5&ss=19> [accessed July 25, 2005].
- Negroponte, Nicholas (1995) *Being Digital*, USA, MIT Press.
- Nervi, Pier Luigi (1965) On the design process, In: Kepes, Gyorgy (ed.) (1965) *Structure in Art and in Science*, London, Studio Vista, pp.105-110.
- Nesbitt, Kate (ed.) (1996) *Theorizing a new agenda for architecture – an anthology of architectural theory 1965-1995*, New York, Princeton Architectural Press.
- Nicol, Andrew (2005a) Interview with the author June 28 2005. Arup Acoustic, Sydney Office, Sydney. [Recording in possession of author].
- Nicol, Andrew (2005b) Interview with the author April 05 2005. Arup Acoustic, Sydney Office, Sydney. [Recording in possession of author].
- Nicol, Andrew (2005c) Interview with the author April 26 2005. Arup Acoustic, Melbourne Office, Melbourne. [Recording in possession of author].
- Nobis, Philip (1994) *Utzon's interiors for The Sydney Opera House - The design development of the Major and Minor Hall 1958-1966*, Dissertation, University of Technology Sydney.
- Norberg-Schulz, Christian (1965) *Intentions in Architecture*, MIT press, Cambridge, Massachusetts
- Oechslin, Werner (1993) The Evolutionary Way to Modern Architecture: The Paradigm of Stilhölse und Kern, In: Mallgrave, Harry Francis (ed.) (1993) *Otto Wagner: Reflections on the Raiment of Modernity*, Issues & Debates vol. 3, Santa Monica, The Getty Center for the History of Art and Humanities, University of Chicago Press, pp. 363-410.
- Østerberg, Dag (2005) *Sociologiske nøglebegreber og deres oprindelse* [Sociological key concepts and their origin], Copenhagen, Akademisk Forlag.
- Pancharatnam, S and Ramachandraiah, A (2003) A Study on the Computer Aided Acoustic Analysis of an Auditorium, *Journal of Architectural Engineering*, Vol. 84, April.
- Parr, Adrian (ed.) (2005) *The Deleuze Dictionary*, Edinburgh, Edinburgh University Press.
- Philip Nobis (2003) *Geometric Harmony*, Arkitektur DK, no. 8, volume 47, pp. 466-487.
- Plume, Jim and Mitchell, John (2005) *A Multi – Disciplinary Design Studio using a Shared IFC Building Model*, In Martens, Bob and Brown, Andre (Eds): *Computer Aided Architectural Design Futures 2005 - Proceedings of the 11th International CAAD Futures Conference*, Vienna University of Technology, Vienna, Austria, June 20-22, 2005, Springer, Dordrecht.
- Quote, Unquote - The Harvard Style of Referencing Published Material (1998) [Internet] Leeds Metropolitan University. Available from: <www.lmu.ac.uk/lskills/open/sfl/content/harvard/downloads> [Accessed 06 March, 2004].
- Rice, Peter (1994) *An engineer imagines*, Artemis, London.
- Rindel, Jens Holger and Naylor, Graham (1992) Predicting Room Acoustical Behaviour with the ODEON Computer Model, *Proceedings of 3aAA3 at the 124th ASA meeting* [Internet]. New Orleans, Available from: <www.odeon.dk/pdf/Asa2.pdf> [assessed 13 September 2006].
- Rindel, Jens Holger, Shiokawa, Hiroyoshi, Christensen, Claus Lynge and Gade, Anders Christian (1999) *Comparisons between Computer Simulations of Room Acoustical Parameters and those Measured in Concert Halls*. Joint Meeting of the Acoustical Society of America and the European Acoustics Association, 14 - 19 March 1999, Berlin.
- Rykwert, Joseph (1972) *On Adam's House in Paradise – The Idea of the Primitive Hut in Architectural History*, The Museum of Modern Art, New York.
- Rykwert, Joseph (1989) *Gottfried Semper: Architect and Historian*, In: Mallgrave, Harry Francis and Hermann, Wolfgang (eds.) (1989) *Gottfried Semper - The four elements of architecture and other writings*, Cambridge, original Cambridge University Press, p. vii-xviii.
- Salomonsen, Per (1995) *Grundlæggende metodebegreber i sociologi* [Fundamental methodological concepts of sociology], 3rd edition, Copenhagen, Akademisk Forlag.
- Schatzki, Theodore R. (2001) *Introduction: Practice theory*. In: Schatzki, Theodore R.; Cetina, Karin Knorr; von Savigny, Eike (eds.) *The Practice Turn in Contemporary Theory*, Routledge, London, 2001.
- Schmidt, A. M. D. and Kirkegaard, P. H. (2005) From Architectural Acoustics to Acoustical Architecture Using Computer Simulation, *Journal of Building Acoustics*, 12 (2), pp. 85-98.
- Schmidt, Anne Marie Due (2005) *Digital Tectonic Tools*, In: *Digital Design - The Quest for New Paradigms*. Proceedings eCAADe no. 23, Lissabon, Portugal, September 21-24, 2005, pp. 657-664.

Schmidt, Anne Marie Due (2006a) Organizations to create tectonic architecture [internet], Aalborg University. Available from: <www.aod.aau.dk/ark/default.htm> [accessed December 27, 2006].

Schmidt, Anne Marie Due (2006b) Public regulations towards a tectonic architecture - Carrots and sticks that could develop the building industry [internet], Aalborg University. Available from: < www.aod.aau.dk/ark/default.htm> [accessed December 27, 2006].

Schmidt, Anne Marie Due and Kirkegaard, Poul Henning (2004a) Arkitekturens ulidelige lethed : simuleringsprogrammer i tektonisk formgivning [The Unbearable Lightness of Architecture – Simulation Programmes in Tectonic Design] In: Per Dombernowsky (ed.) Proceedings from Nordisk Tekniklæremøde, School of Architecture, Aarhus, 10-11 June 2004, pp. 67-74.

Schmidt, Anne Marie Due and Kirkegaard, Poul Henning (2004b) On Architectural Acoustics Design using Computer Simulation. In: Proceedings of the Eleventh International Conference on Sound and Vibration, St. Petersburg, Russia, 5-8 July 2004. Nickolay I. Ivanov; Malcolm J. Crocker (eds.). International Institute of Acoustics and Vibration (IIAV), pp. 647-654.

Schmidt, Anne Marie Due and Kirkegaard, Poul Henning (2005) Navigating towards digital tectonic tools. In: Conference of the Association for Computer Aided Design in Architecture, October 13-16, 2005, Savannah (Georgia), Smart Architecture: Integration of Digital and Building Technologies, pp. 114-127.

Schmidt, Anne Marie Due and Kirkegaard, Poul Henning (2006) Tectonic transformation : the architect as an agent of change, In: Proceedings from Annual symposium of the Nordic Association for Architectural Research, The Royal Academy of Fine Arts, School of Architecture, Copenhagen, Denmark, pp. 130-137.

Schodek, Daniel; Bechthold, Martin; Griggs, James Kimo; Kao, Kenneth; Steinberg, Marco (2004) Digital Design and Manufacturing: CAD/CAM Applications in Architecture, John Wiley & Sons.

Schön, Donald A. (1983) The Reflective Practitioner – How Professionals Think in Action, United States of America, Basic Books.

Schwarzer, Mitchell (1993) Ontology and Representation in Karl Botticher's Theory of Tectonics, Journal of the Society of Architectural Historians, 52, pp. 267-80.

Schwarzer, Mitchell (2004) Zoomscape – Architecture in Motion and Media, New York, Princeton Architectural Press.

Sekler, Eduard (1965) Structure, Construction, Tectonics, In: Kepes, Gyorgy (ed.) (1965) Structure in Art and in Science, London, Studio Vista, pp.89-95.

Semper, Gottfried (1851) The Four Elements of Architecture – A contribution to the Comparative Study of Architecture, In: Mallgrave, Harry Francis and Herrmann, Wolfgang (1989) Gottfried Semper - The four elements of architecture and other writings, Cambridge University Press, Cambridge, 1989, pp. 74-129.

Semper, Gottfried (1852a) Science, Industry, and Art – Proposals for the Development of a National Taste in Art at the Closing of the London Industrial Exhibition, In: Mallgrave, Harry Francis and Hermann, Wolfgang (eds.) (1989) Gottfried Semper - The four elements of architecture and other writings, Cambridge, original Cambridge University Press, pp. 130-167.

Semper, Gottfried (1852b), Prospectus: Comparative Theory of Building, In: Mallgrave, Harry Francis and Hermann, Wolfgang (eds.) (1989) Gottfried Semper - The four elements of architecture and other writings, Cambridge, original Cambridge University Press, pp. 168-173.

Semper, Gottfried (1859), Prospectus: Style in the Technical and Tectonic Arts or Practical Aesthetics, In: Mallgrave, Harry Francis and Hermann, Wolfgang (eds.) (1989) Gottfried Semper - The four elements of architecture and other writings, Cambridge, original Cambridge University Press, pp. 174-180.

Semper, Gottfried (1860) Style in the Technical and Tectonic Arts or Practical Aesthetics, In: Mallgrave, Harry Francis and Herrmann, Wolfgang (1989) Gottfried Semper - The four elements of architecture and other writings, Cambridge University Press, Cambridge, 1989, pp. 181-263.

Semper, Gottfried (1869), On Architectural Styles, In: Mallgrave, Harry Francis and Hermann, Wolfgang (eds.) (1989) Gottfried Semper - The four elements of architecture and other writings, Cambridge, original Cambridge University Press, pp. 164-284.

Skrzynski, Joseph (2005). Interview with the author February 3 2005. Champ & Champ Ventures, Sydney. [Recording in possession of author].

Smith, Michael Pomeroy (1984) Sydney Opera House – How it was built and why it is so, Sydney Collins.

Spuybroek, Lars (2003) Textile Tectonics, In: Tschumi, Bernard and Cheng, I (eds.) The state of architecture at the beginning of the 21st century, New York, The Monacelli Press, pp. 102-103.

- Stacey, Michael (ed.) (2004) *Digital Fabricators*, University of Waterloo School of Architecture Press, Toronto.
- Stake, Robert E. (1995) *The Art of Case Study Research*, Thousand Oaks, California, Sage Publications.
- Stevens, Garry (1998) *The Favored Circle – The Social Foundations of Architectural Distinction*, Cambridge, Massachusetts, MIT Press.
- Sydney Opera House Competition (1957) *The Builder*, March, vol. 192, pp. 399-407.
- Sydney Opera House Trust (1998) *Annual Report*, Sydney.
- Sydney Opera House Trust (1999) *Annual Report*, Sydney.
- Sydney Opera House Trust (2001) *Annual Report*, Sydney.
- Sydney Opera House Trust (2002) *Annual Report*, Sydney.
- Sydney Opera House: engineer's view (1966) *Architectural Record*, January, pp. 175-180.
- Sydney Opera House: The Engineer's Story (1965) *Architectural Record*, November, pp. 197-198.
- Szalapaj, Peter (2001) *CAD Principles for Architectural Design – Analytical Approaches to Computational Representation of Architectural Form*, Oxford, Architectural Press/Elsevier.
- Szalapaj, Peter (2005) *Contemporary Architecture and the Digital Design Process*, Oxford, Architectural Press/Elsevier.
- Thomassen, Mikkel (2005) Byggeriets fremtidige organiserings [The future organization of the Building Industry], *Arkitekten* 6, volume 107, pp. 8-13.
- Tombesi, Paolo (2004) Architectural feasts or professional fausts? A double perspective on the bargains of globalization: what are the opportunities and potential costs of a globalized architectural market? *Architecture Australia*, Volume 93, July-August, pp. 48-51.
- Tombesi, Paolo (2005) Iconic Public Buildings as Sites of Technological Innovation. *Harvard Design Magazine* 21 [Internet] Fall 2004/Winter 2005, Available from: <www.gsd.harvard.edu/research/publications/hdm/current/21_tombesi.html> [accessed February 20, 2006].
- Tremlett, Giles (2002) Master of the house, *Newcastle Herald*, April 06, p. 12.
- Turnbull, David (2004) An Aesthetics Of Calculus, In: Leach, Neil; Turnbull, David; Williams, Chris (eds) (2004) *Digital tectonics*, UK, Wiley-Academy, pp. 142-149.
- Turner, Brook (1999) Utzon accepts Opera House role, *Australian Financial Review*, August 12, p. 38.
- Turner, James A. and Barnett, Norman E. (1998) Architectural acoustic teaching software, *Automation in Construction*, vol. 8, no. 1, November 1998, pp. 107-123.
- Turner, James A. and Hall, Theodore W. (1990) An Application of Geometric Modeling and Ray Tracing to the Visual and Acoustical Analysis of a municipal open-air Auditorium, In: Jordan, Peter (ed.) *Proceeding of ACADIA Workshop - From Research to Practice*, October 1990, Big Sky, Montana, pp. 173-185.
- Twombly, Robert (ed.) (2003), *Louis Kahn – Essential texts*, New York, W.W. Norton and Company.
- Tzonis, Alexander and Lefaivre, Liane (1990) Why Critical Regionalism Today? In: Nesbitt, Kate (ed.) (1996) *Theorizing a new agenda for architecture – an anthology of architectural theory 1965-1995*, New York, Princeton Architectural Press, pp. 484-492.
- Utzon, Jan (1988) *Tre Generationer [Three Generations]*, Rungsted Kyst, Internationalt Forlag.
- Utzon, Jan (2006) Interview with the author April 26 2006. Telephone interview. [Recording in possession of author].
- Utzon, Jørn (1965a) Report on Acoustics, Unpublished, Mitchell Library Collection, ML MSS 2362/21, Sydney.
- Utzon, Jørn (1965b) *The Sydney Opera House*, *Zodiac* 14, pp. 48-49.
- Utzon, Jørn (2002) *Sydney Opera House, Utzon Design Principles*, [Internet] Sydney Opera House Website. Available from: <www.sydneyoperahouse.com/sections/corporate/about_us/pdfs/aboutus_utzon_design_principles.pdf>. [Accessed February 15, 2005]
- Utzon, Jørn and Faber, Tobias (1947) Tendenser i Nutidens Arkitektur [Tendencies in Contemporary Architecture], *Arkitekten*, vol. 49, nos. 7, 8 and 9, July, August, September, pp. 63-69.
- Utzon, Jørn; Weston, Richard; Bløndal, Torsten (ed.) (2005) *Jørn Utzon Logbog Vol. II, Bagsværd Kirke [Jørn Utzon Logbook Vol. II, Bagsværd Church]*, Hellerup, Edition Bløndal.
- Vallhonrat, Carles (1988) *Tectonics Considered. Between the Presence and the Absence of Artifice*, *Perspecta*, vol. 24, pp. 122-135.

Introduktion: Ku
Method: Yokoh
Minor Hall: West
Opera Theatre: D
Conclusion: Mira

Vallhonrat, Carles (2000) The In-Visibility of Tectonics. Gravity and the Tectonic Compacts, *Perspecta*, vol. 31, pp. 22-35.

Verghis, Sharon (2005) Utzon, utzoff: Opera House facelift sags, *Sydney Morning Herald*, April 1.

Virilio, Paul (2000) *The Information Bomb*, London and New York, Verso.

Vitruvius, Pollio. *The Ten Books on Architecture*, Translated by Morris Hicky Morgan (1960), New York, Dover Publications.

Weston, Richard (2001) *Utzon*, Germany, Edition Bløndal.

Woodger, Neill (2006) *Acoustical Engineering*, In: Chaszar, André (ed) (2006) *Blurring the Lines*, *Architecture in Practice*, Great Britain, Wiley-Academy, pp. 148-157.

Yeomans, John (1968) *The other Taj Mahal – what happened to the Sydney Opera House*, Plymouth, Longmans, Green and Co.

Yin, Robert K. (1994) *Case Study Research – Design and Methods*, 2nd edition, *Applied Social Research Methods Series Volume 5*, California, Sage Publications.

Young, Victor (2005) *Shade, but no poetry*, *The Australian*, 22 April, p. 19.

Zellner, Peter (ed.) (1999) *Hybrid Space – New Forms in Digital Architecture*, London, Thames & Hudson.

Zhang, Yan (2005) *A Method to Predict Reverberation Time in Concert Hall Preliminary Design Stage*, Georgia, Georgia Institute of Technology.

Zunz, Jack (1988) *Sydney Revisited*, *The Arup Journal*, Spring, Vol. 23, No. 1, pp. 2-11.

Zurbrugg, Nicholas (ed.) (1997) *Jean Baudrillard, Art and Artefact*, Wiltshire, Sage Publications.

ILLUSTRATION CREDITS

Please note that while every effort has been made to obtain permission to use the illustrations in this report this has not been possible for all the illustrations. While this is acceptable for the purpose of a PhD-report, all permissions would be obtained for a future publication.

FRONTPAGE

Cover: Sketch by Jørn Utzon. Weston, Richard (2001) Utzon, Germany, Edition Bløndal.

INTRODUCTION

Figure p. 10: Kuursaal by Raphael Moneo (2004) [online image]. Available from <<http://www.epdlp.com>>, [Accessed 15 February 2004].

Figure 1: Larsen, Lena; Mossin, Natalie; Beim, Anne (2002) Økologi og arkitektonisk kvalitet [Ecology and architectural quality], Arkitektskolens Forlag, with permission from Arkitektskolens Forlag.

Figure 2-6: Gypmel, Jan (1996) Arkitekturens historie fra antikken til i dag [The history of architecture from antiquity till today], Germany, Könemann.

Figure 7-8: Tietz, Jürgen (2000) Arkitekturens Historie i det 20. århundrede [The history of architecture in the 20th century], Germany, Könemann.

Figure 9-11: Briggs, Asa (1979) Iron Bridge to Crystal Palace – Impact and Images of the Industrial Revolution, London, Thames and Hudson.

Figure 12: Gypmel, Jan (1996) Arkitekturens historie fra antikken til i dag [The history of architecture from antiquity till today], Germany, Könemann.

Figure 13: Benevolo, Leonardo (1996) History of Modern Architecture, vol. 1 and 2, Third translated edition, Cambridge, Massachusetts, MIT Press.

Figure 14: Beijing Stadium by Herzog & De Meuron (2004) [online image]. Available from <www.ethlife.ethz.ch/images/stadionpeking-l.jpg>, [Accessed 15 February 2004].

Figure 15: Kolarevic, Branko (ed.) (2003) Architecture in the Digital Age – Design and Manufacturing, New York, Spoon Press, Taylor & Francis.

METHODOLOGY

Figure p. 36: Sakamoto, Tomoko (ed.) (2003) The Yokohama Project, Architecture Boogazine, Processing, actar.

Figure 1: Author's diagram

Figure 2: Author's photograph

Figure 3: Author's diagram

Figure 4: Author's diagram

THE CONCEPT OF TECTONICS

Figure 1: Bötticher, Carl (1844) Die Tektonik der Hellenen, Potsdam, Riegel.

Figure 2: Villa Rotunda by Palladio [online image]. Available from <www.greatbuildings.com>, [Accessed 30 July 2006].

Figure 3: Vitra Fire Station by Zaha Hadid (1995) [online image]. Available from <www.bcn.es>, [Accessed 30 July 2006].

Figure 4-5: Gypmel, Jan (1996) Arkitekturens historie fra antikken til i dag [The history of architecture from antiquity till today], Germany, Könemann.

Figure 6-10: Semper, Gottfried (2004) Style in the Technical and Tectonic Arts; or, Practical Aesthetics, Translation by Harry Francis Mallgrave, Los Angeles, Getty Research Institute.

Figure 11: Tietz, Jürgen (2000) Arkitekturens Historie i det 20. århundrede [The history of architecture in the 20th century], Germany, Könemann.

Figure 12: Guggenheim Bilbao by Frank Gehry (2000) [online image]. Available from <www.greatbuildings.com>, [Accessed 17 April 2006].

Figure 13: Author's photograph

Figure 14: Author's diagram

Figure 15: Author's diagram

THE CONCEPT OF TECTONICS IN THE DIGITAL ERA

Figure 1: Water Pavilion by NOX [online image]. Available from <www.vitruvius.com.br>, [Accessed 4 August 2006]

Figure 2-4: Dal Co, Francesco and Forster, Kurt W. (1998) Frank O. Gehry: The Complete Works, Electa

Figure 5: Highrise by Reiser and Umemoto (2005) [online image]. Available from <www.reiser-umemoto.com/>, [Assessed 15 April 2006].

Figure 6: Sakamoto, Tomoko (ed.) (2003) The Yokohama Project, Architecture Boogazine, Processing, actar.

Figure 7: Carnegie Science Centre by UN studio (2006) [online image]. Available from <www.unstudio.com>, [Accessed 4 August 2006]

Figure 8: Gregg Lynn experimentations with ornaments [online image]. Available from <www.glform.com/>, [Accessed 17 April 2006]

Leach, Neil; Turnbull, David; Williams, Chris (eds) (2004) Digital tectonics, UK, Wiley-Academy,

Leach, Neil; Turnbull, David; Williams, Chris (eds) (2004) Digital tectonics, UK, Wiley-Academy,

Figure 9: Author's diagram

Figure 10: Author's diagram

Figure 11: Author's diagram

Figure 12-14: Leach, Neil; Turnbull, David; Williams, Chris (eds) (2004) Digital tectonics, UK, Wiley-Academy,

MINOR HALL CASE

Figure p. 94: Weston, Richard (2001) Utzon, Germany, Edition Bløndal.

Figure 1: Zunz, Jack (1988) Sydney Revisited, The Arup Journal, Spring, Vol. 23, No. 1, pp. 2-11.

Figure 2: Author's photograph

Figure 3-8: Weston, Richard (2001) Utzon, Germany, Edition Bløndal.

Figure 9: Malcolm Quantrill (1983) Alvar Aalto: A Critical Study, New York, Schoken Books.

Figure 10: Nobis, Philip (1994) Utzon's interiors for The Sydney Opera House - The design development of the Major and Minor Hall 1958-1966, Dissertation, University of Technology Sydney.

Figure 11: Weston, Richard (2001) Utzon, Germany, Edition Bløndal.

Figure 12: Utzon, Jørn (1965b) The Sydney Opera House, Zodiac 14, pp. 48-49.

Figure 13: Jones, Peter Blundell and Kang, Jian (2003) Acoustic form in the Modern Movement, Architectural Research Quarterly, vol. 7, no. 1.

Figure 14: Gutheim, Frederick (1960) Alvar Aalto, The Masters of World Architecture Series, New York, George Braziller.

Figure 15-17: Nobis, Philip (1994) Utzon's interiors for The Sydney Opera House - The design development of the Major and Minor Hall 1958-1966, Dissertation, University of Technology Sydney.

Figure 18-22: Utzon, Jørn (1965b) The Sydney Opera House, Zodiac 14, pp. 48-49.

Figure 23: Weston, Richard (2001) Utzon, Germany, Edition Bløndal.

Figure 24-25: Nobis, Philip (1994) Utzon's interiors for The Sydney Opera House - The design development of the Major and Minor Hall 1958-1966, Dissertation, University of Technology Sydney.

Figure 26: Weston, Richard (2001) Utzon, Germany, Edition Bløndal.

Figure 27: Holm, Michael Juul (ed.) (2004) Jørn Utzon: The architect's universe, Louisiana Revy, no. 2, Photograph by Vilhelm Jordan/Jørn Utzon.

Figure 28: Jones, Peter Blundell (1995) Hans Scharoun, London, Phaidon Press.

OPERA THEATRE CASE

Figure p. 126: Johnson, Pilton, Walker (2005) Design Development Sydney Opera House, Internal working document, with permission from Jan Utzon.

Figure 1: Author's photograph

Figure 2: Author's photograph

Figure 3: Courtesy of Eoghan Lewis

Figure 4: The current Opera Theatre (2003) [online image] Available from: <www.sydneyoperahouse.com>, [Accessed 2 February 2005].

Figure 5-8: Johnson, Pilton, Walker (2005) Design Development Sydney Opera House, Internal working document, with permission from Jan Utzon.

Figure 9-20: Barron, Michael (1993) Auditorium Acoustics and Architectural Design, Bath, E & FN Spon.

Figure 21: McDermott Hall (1989) [online image] Available from: < www.artec-usa.com>, [Accessed 23 December 2006].

Figure 16-27: Johnson, Pilton, Walker (2005) Design Development Sydney Opera House, Internal working document, with permission from Jan Utzon.

CASE COMPARISON

Figure 1: Nobis, Philip (1994) Utzon's interiors for The Sydney Opera House - The design development of the Major and Minor Hall 1958-1966, Dissertation, University of Technology Sydney.

Figure 2: Johnson, Pilton, Walker (2005) Design Development Sydney Opera House, Internal working document, with permission from Jan Utzon.

Figure 3: Author's diagram

Figure 4: Author's diagram

Figure 5: Nobis, Philip (1994) Utzon's interiors for The Sydney Opera House - The design development of the Major and Minor Hall 1958-1966, Dissertation, University of Technology Sydney.

Figure 6: Johnson, Pilton, Walker (2005) Design Development Sydney Opera House, Internal working document, with permission from Jan Utzon.

Figure 7: Author's diagram

Figure 8: Author's diagram

Figure 9: Author's diagram

CONCLUSION AND PERSPECTIVES

Figure p. 166: Concrete casting [online image]. Available from <www.arcspace.com/architects/miralles/parliament/>, [Accessed 4 August 2006]